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The Orthopaedic Hospital of the Invalid Foundation Helsinki Finland

FLEXORPLASTY OF PARALYTIC ELBOWS

Analysis of Late Functional Results

T Sam Lindholm & Sakari Einola

Accepted 9 x 72

A method for surgical management of flexion paresis of the elbow joint was published by Arthur Steindler in 1918 He transposed the insertion of the flexor group of the wrist and fingers from the median epicondyle of the humerus proximally to the diaphysis of the humerus and thus increased the leverage of these muscles on the elbow joint without impairing their original function Modifications of the method have been presented by e g Bunnell (1951) who used a fascial trans plant as continuation to the muscle group and Mayer & Green (1954) who attached the epicondyle to the volar aspect of the humerus Both these methods seek to move the insertion from the median surface of the humerus more laterally in order to prevent pronation contracture Mayer & Green (1954) tried to reinforce the result of flexorplasty by also moving the extensor group proximally but abandoned this method because of the risk of nerve damage that it involved

Other alternatives have been suggested for the restoration or improve ment of the flexion of the elbow joint The transposition of pectoralis major to biceps introduced by Clark (1946) and modified by Brooks & Seddon (1959) of sternocleidmastoideus to biceps by Bunnell (1951) and of triceps by Carroll (1952) which are mentioned as the main alternatives to Steindler s method are not discussed here The present material consists of cases in which transposition of Steindler s flexor group was the basic procedure used in the treatment of flexion paresis of the elbow joint

METHOD

The ulnar nerve was freed and protected during the operation The median epi cond le or part of it was detached b chisel and the flexor group was dissected Detachment from the epicond le was done subperiosteally in children The freed muscle bundle was fixed to the medial or mediovolar surface of the humerus 2 5

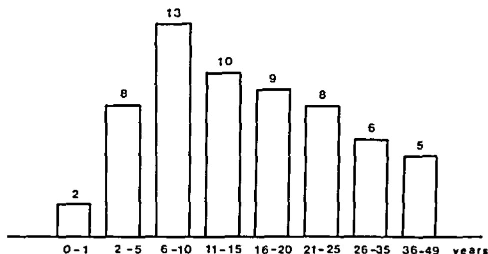


Figure 1 Age distribution at the onset of poliomyelitis or time of lesion More than half of the patients were diseased between 0 and 15 years

cm proximally mostly into a periosteal pocket and septum intermusculare In 7 cases the fixing wire was pulled through a hole drilled in the bone The epicondyle fragment was fixed by screw in 2 cases The lateral extensor group was also transposed 3-7 cm proximally in 6 cases in 2 of them at a separate operation Bunnell s fascial transplant was used in one case After the operation the limb was immobilized in plaster of Paris flexed 90 or less and with the forearm in maximal supination for six weeks Physiotherapy was started after removal of the cast

Four patients underwent humeroscapular arthrodesis 2 carpal arthrodesis and in another 2 cases transposition of the flexor carpi ulnaris was performed

MATERIAL

The series comprised 61 cases 59 with a post poliomyelitis status one obstetric and one postoperative upper limb paresis The patients had been operated on at the Orthopaedic Hospital of the Invalid Foundation in 1946–1966 and given a follow up examination in 1960 and 1971 Two thirds of the patients were followed up 6–15 years after the operation 34 were women and 27 men The operation was performed 29 times on the left and 32 on the right side The ages of the patients at the onset of the illness at the operation and interval between onset and surgery are presented in Figures 1–3

In 33 cases one upper limb was affected whereas the pareses were more extensive in the remaining 28 cases Six patients had pareses of the digital flexors 4 of the extensors 15 on the flexor side of the wrist and 6 on its extensor side Involving

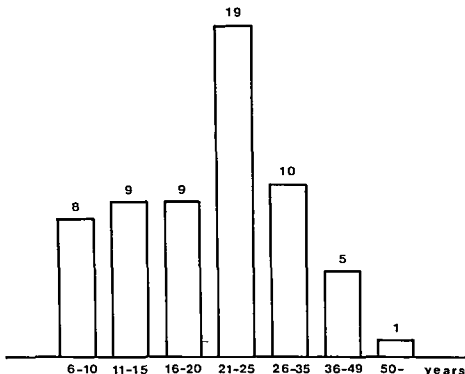


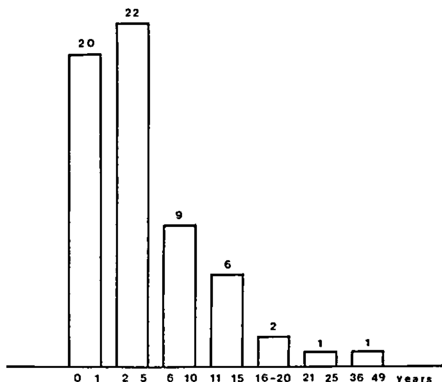
Figure 2 Age distribution at the time of operation About three fourths of the patients were operated between 6 and 25 years with the maximum rate at 21-25 years

one or some of the muscles in question Paresis of both the finger and wrist muscles was observed in 11 cases Complete flexion paresis in the elbow joint was present in 26 cases combined with totally paretic triceps in 20 cases The ipsilateral humeroscapular muscles of 40 patients were either completely or largely paretic causing subluxation of the humerus

FOLLOW UP

Elbow Flexion

Forty six of the patients considered subjectively that they had derived distinct benefit from the operation All but 5 of the patients were able to make a flexion extension movement of the operated elbow (Figure 4) One patient was able to lift 2 kg and 10 could lift 1 kg at right angles Eighteen patients were able to handle light objects and



igure 3 The periods up to the time of operation Two thirds of the patients were operated 0–5 years after the occurrence of the disease

to lift 200 g within the full range of movement The strength of the active flexion was consequently equal to or slightly greater than the gravitational force in 27 cases

Evaluation of the *strength of flexion* in the 11 patients who were able to lift a weight of over 1 kg at right angles revealed that they all had normal or only slightly reduced strength in the hand and wrist In 7 cases the preoperative limitation of extension was over 30 and in the patient with the best flexion rating it was 55 In the other cases some degree of flexion function was preserved in the natural elbow flexores before the operation

Maximal strength of flexion was achieved in one of the patients where combined transposition of the median flexor group and the lateral extensor group was performed but the same case displayed the maximum extension limitation No clear evidence of increased exten

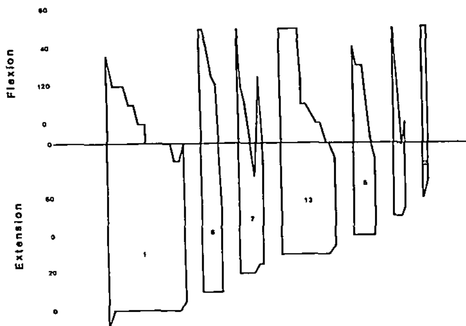


Figure 4 The range of movement achieved in 56 patients with flexorplasty of the elbow 5 patients had no active movement at the follow up examination The active movement is arranged according to the limitation of extension and the degree of flexion Preoperatively three fourths of the patients had no active function of biceps two fifths no active triceps The major part of the patients hold the elbow in a straight position in 7 cases there was a limitation of extension over 30 in one case about 55

sion contracture or flexion strength by this method could be found in the other cases

The patients with a paretic shoulder said that they often supported the elbow joint against the table which enabled them to increase the flexion strength of the joint This was confirmed in these cases by supporting the paretic shoulder when the strength of flexion was studied

Degree of elbow flexion The range of movement achieved in the elbow joint can be seen in Figure 4 Many of the patients preferred to flex the elbow with a clenched hand There were 3 cases in which the forearm was pronated 4 in which the wrist was in volar flexion and one in which it was in supination when the movement was performed The fingers and wrist of 7 patients were in pronounced hyperflexion on performing the movement the extension strength rat

ing of the fingers and wrist of these patients was nil The patients with loosening of the transposed median epicondyle retained some biceps and brachial function which obviously helped to increase flexion strength One patient had such a poor muscular strength rating in the limb that he felt the operation had been of no benefit although he was able to flex the limb Fixation had been done 2-2½ cm proximally in another 2 cases and was probably a major reason for the poor flexion strength One of these 2 patients had moreover undergone transposition of the extensor group 7 cm proximally but it obviously did not affect the strength of flexion It was impossible to decide with certainty in 2 cases why the result was poorer than expected Both of these patients however considered that surgery had been of considerable benefit one was capable of lifting 200 g with the hand clenched

Elbow Extension

No *limitation of extension* was observed in 18 patients The preoperative flexion strength of the forearm had been nil in all these cases 4 were capable of flexing it under 120 at the follow up examination and all of them had good muscle strength in the wrist and fingers The extension strength of the elbow joint was rated 0 in 7 cases An increased limitation in extension postoperatively is a fact in many cases

Supination and Pronation

Pronation contracture of varying degree was established in 17 patients at the follow up In 14 of them the strength of supination preoperatively had been rated 0 and the degree of pronation good The strength ratio was distinctly in favour of pronation in the remaining 3 cases Six of these 17 patients had a contracture in pronation preoperatively Slight limitation of supination was seen in 14 cases in these cases too the strength of pronation was distinctly greater than the degree of supination or both were nil

The strength of pronation supination was equal in the remaining 30 cases or supination was stronger than pronation The supination rating had increased during the six follow up years in 9 cases One patient s forearm turned to supination on bending the epiphyseal transplant had worked loose

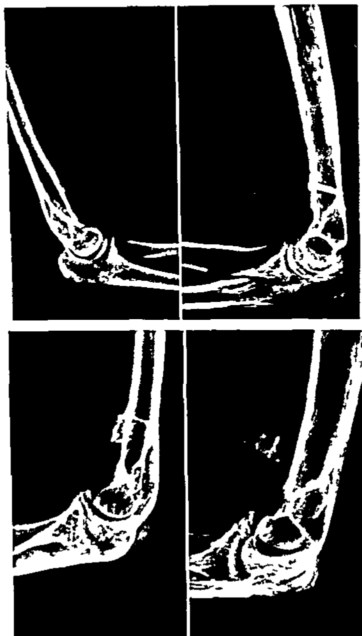


Figure 5 A series of roentgenograms of the state of the transposed medial epi condyle ad modum *Steindler at follow-up In the last example the epicondyle has broken loose from its attachment to the bone*

Complications

There were symptoms in 2 cases of damage to the ulnar nerve. The paresthesia disappeared in one case in a few months but the other patient still complained of that at the follow-up examination. The roentgenograms taken at the follow-up showed that the transposed median epicondyle had worked loose from its periosteal attachment in three cases and the lateral epicondyle had loosened in one case. Not a single transplant fixed to bone had worked loose (Figure 5).

DISCUSSION

The primary object of Steindler's flexorplasty is to reactivate or increase the range of elbow flexion so that the patient can raise his working hand to the right level. The importance of this simple movement in e.g. desk work or even just raising the hat is obvious. Fifty of the 61 cases of this series achieved a range of flexion of at least 90°. Some of these patients did not meet the other important criterion of flexorplasty, that is, a hand functioning sufficiently well for the patient to benefit from the intervention.

The main requirement for achievement of good flexion mobility and strength with Steindler's method is the condition of the muscle group to be transposed, provided that the procedure has been correctly performed technically. This has been stressed not only by the creator of the method but also by all other investigators. In the present material the function of both the flexors and extensors of the fingers and the wrist was either not or only slightly impaired in the groups with the best range of motion and in the best cases as regards strength of flexion. In contrast, absence of function in the extensor group made the hand useless in the two cases in which flexing of the elbow joint caused maximal flexion in both the fingers and the wrist.

An ideal end result is good flexion strength and good range of motion, *which are to some extent parallel requirements. In this series* the best "lifters" of each group were the patients who achieved a fairly good range of mobility. The best result achieved, that is 2 kg, matches the best in Nyholm's (1963) series. The best strength of flexion achieved by Kettelkamp & Larson (1963) was 3 kg.

The recommended distance of transposition for the medial epicondyle is approx. 5 cm, sometimes a little more. In most of the present cases the epicondyle was transposed some 3–4 cm proximally, judging by the control roentgenograms. The poor flexion strength in some

cases was attributed at least partly to the short (about 2 cm) distance of transposition Indeed it seems natural that if the strength of the transposed flexor group is reduced a better flexing strength might be achieved with a longer transposition distance though an increase in the extension limitation would then have to be expected Bunnell s (1951) method of using a fascial transplantate as a continuation for the muscle group gives a longer lever arm for weak muscles and possibly reduces the limitation of extension

Limitation of extension in the elbow joint often follows flexorplasty It was an average of 15–20 in Nyholm s (1963) material 30 in that of Mayer & Green (1954) 40 in Carroll s (1952) series and 60 in the material reported by Segal et al (1959) In the present material the average extension limitation was 25

The strength of the triceps has been considered to be correlated with the limitation of extension (Mayer & Green 1954) In the first two groups of this series in which the extension limitation was not over 10 at most the triceps were in good condition and the muscle group to be transposed was practically normal in the majority of the cases The range of mobility achieved in these cases was good This suggests that a new antagonist muscle in good condition would seem to have a favourable effect on the function of the transposed muscle group On the other hand a severely paretic triceps appears to increase the limitation of extension as evidenced by the distribution of the triceps–0 patients in the material

The cases in which both the extension and flexion strength was completely paretic because of paralysis were among the poorest because of the concurrent weakness of the muscle group to be transposed This paretic combination also appears to be reflected in the degree of impairment of the other muscle of the limb The pronounced extension limitation of one patient was obviously a part factor in the achievement of good strength of flexion with unimpaired muscles of the forearm a finding in agreement with earlier observations (Segal et al 1959 Nyholm 1963) It should be noted that this patient had also undergone transposition of the extensor group which has been considered to be of significance for the magnitude of the limitation of extension Incidentally transposition of the extensor group was not found to have any definite effect on the flexion strength achieved

One of the major drawbacks of Steindler s method is the tendency to pronation contracture It was observed in almost one third of the cases at the follow up examination This must be regarded as the

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EXTRADURAL PSEUDOCYSTS

A Cause of Pain after Lumbar Disc Operation

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Extradural cysts may be either congenital or acquired The most frequent site of the congenital cyst is the mid thoracic region but a few with lumbar and cervical localization have also been described (Wiese & Foster 1955 Smith & Chavez 1958 Gortvai 1963 Glasauer 1966) They are often associated with osseous changes in the spine such as kyphosis scoliosis and widening of the interpedicular distance (Dastur 1963) These cysts are most commonly encountered in patients aged from 20 to 50 years

The acquired cysts develop after surgery or less frequently trauma to the spine They are mentioned in the literature under such names as meningeal pseudocysts spurious meningocele or extradural arachnoid cysts As the meninges are not necessarily involved in the formation of the cyst wall we find that a more accurate term would be *extradural pseudocysts*

The purpose of this paper is to present three cases of postoperative extradural pseudocysts and to contribute to the discussion on the causes of unsatisfactory results from the operative treatment of lumbar disc lesions

CASE REPORTS

Case 1 A 47 year old woman operated in 1965 and 1968 for herniation of the fifth lumbar disc In 1970 laminectomy was performed for herniation of the third and fourth lumbar disc A month after discharge lumbar pain recurred now radiating down the left leg posteriorly to the heel There was also pain localized to the coccyx radiating towards the anus The pain could be provoked by forward bending of the head and increased in intensity on abdominal straining Paraesthesiae localized to the lateral border of the left foot and its lateral toes were present

Delicate palpation of the lumbar region elicited violent pain and fluctuation was demonstrated On the lower limbs hypaesthesiae of the lateral border of the



Figure 1 Case 1 Lumbar myelogram demonstrating an extradural lake of contrast

left foot and its two lateral toes was revealed Lasegue s sign was negative on both sides Conray myelography showed a massive contrast filling behind the dural sac (Figures 1–3)

In 1971 an extradural pseudocyst was removed measuring 11 × 5 × 4 cm It contained cerebrospinal fluid In the cavity there were two dural perforations the upper of which contained a hernia of caudal nerve roots The hernia was reduced and the dural defects were closed No signs of root compression or of recurring prolapse were noticed Histological examination of the cyst wall revealed a membrane internally lined by flat uncharacteristic cells on a layer of connective tissue cells

At a follow up examination 3 months after operation the patient was almost symptom free Some lumbar pain was still present when the spine was subjected to physical strain

Case 2 A 26 year old woman operated on twice for herniation of the fifth lumbar disc in 1967 The symptom recurred and in 1968 laminectomy on the fourth and fifth lumbar vertebrae was performed revealing pronounced scar formation around the dural sac severe arachnoiditis was seen on opening of the dural sac The pain persisted and in 1968 division of the right thoracic lateral spinothalamic tract was performed. The patient was free of discomfort for four months but then progressively severe lumbar pain with radiation in the right lower limb developed The pain aggravated on abdominal straining Physical examination showed fixation of the lumbar region and tenderness on palpation and pressure on the lower lumbar vertebrae. Weakness of dorsiflexion of the left



Figure 2



Figure 3

Figure 2 + 3. Case 1. An extradural pseudocyst is shown in two planes stretching from the lower border of the third lumbar vertebrate to the sacrum.

foot and the left first toe were noticed. Lasègue's sign could not be elicited. Conray myelography (Figure 4) showed a large contrast filled cavity behind and to the left of the dural sac.

In 1969 resection of the cyst was performed. Downwards in the left side of the dural sac there was a small perforation from which cerebrospinal fluid leaked out. No disc lesion was found.

Histological examination of the cyst showed a membrane resting on a layer of collagen parallel fibres shading into loose connective tissue with a large number of proliferating vessels surrounded by lymphocytic infiltrations.

Postoperatively some improvement was seen, but the symptoms of severe arachnoiditis gradually recurred causing great discomfort to the patient.

Case 3. A 23 year old man, operated for herniation of the fifth lumbar disc in 1963 and again in 1966. The last operation resulted in complete relief of pain, but in 1968 symptoms of root compression developed. A new operation revealed a cyst downwards in the operative cavity measuring 3 × 3 × 1 cm and containing cerebrospinal fluid. The cyst was not excised, but sealed off from the dural sac. In addition, a herniation from the fifth disc was removed. Since this last operation the patient has been completely free of symptoms.



Figure 4 Case 2 Lumbar myelogram (Pantopaque) prone showing a compression of the dural sac caused by an extradural pseudocyst Arachnoiditic changes are evident

PATHOGENESIS

Acquired extradural cysts arise from a defect in the dura Herniation of the arachnoid may develop through the defect so that the arachnoid forms part of the cyst wall (Schurr 1955 Rosenblum & Derow 1963) If the lesion involves the arachnoid cerebrospinal fluid escapes into the surrounding extradural tissue Normally the fluid will be absorbed but if the escape of liquor continues the absorption mechanism becomes insufficient owing to protein precipitation and connective tissue reaction (Shahinfar & Schechter 1966) Thus a non absorbing membrane develops forming the wall of the pseudocyst Histological examination of the wall shows either arachnoid lining or a layer of flat connective tissue cells resting on an outer layer of vascular loose connective tissue (Shahinfar & Schechter 1966 Miller & Elder 1968) At the hole in the dura a thickened fibrous edge develops Herniation of a nerve root through the hole in the dura may occur (Wilkinson 1971)

CLINICAL FEATURES

The symptoms of an extradural pseudocyst are often the same as those experienced in herniation of a lumbar disc They are back pain radicular pain loss of muscular power and sensory disturbances In addition meningeal symptoms such as headache and neck pain may occur (Hyndmann & Gerner 1946 Swanson & Fincher 1947 Borgström 1954 Pagni et al 1961 Rosenblum & Derow 1963 Shahinfar & Schechter 1966 Miller & Elder 1968 Rinaldi & Peach 1969) The pain may increase in intensity on abdominal straining and on changes in posture

Clinical examination may reveal signs of root involvement such as pareses sensory disturbances and changes in the deep reflexes Neck stiffness may be present The lumbar spine is fixed and spasms of the paravertebral muscles are often present A fluctuant mass may occasionally be palpated and sometimes the pain and headache are accentuated by pressure on the cyst The cyst may be so large that the skin bulges outward There is no correlation between the size of the pseudocyst or of the dural defect and the severity of the pain or other symptoms The time interval between the occurrence of the defect in the dura and the discovery of the cyst may vary from a few months to several years

RADIOGRAPHIC APPEARANCE

Plain radiographs of the lumbar spine usually do not reveal the presence of an extradural pseudocyst Sequelae of a previous laminectomy or traumata to the spine or narrowing of the intervertebral spaces or marginal osteophytes may be visualized A few cases are on record in which radiographs demonstrated calcified areas in extradural pseudocysts (Rosenblum & Derow 1963 Shahinfar & Schechter 1966) Myelographs with a water soluble contrast medium will often secure the diagnosis Cases have been described in which the injection needle directly entered an extradural pseudocyst (Shahinfar & Schechter 1966) On subarachnoid injection of the contrast medium it is possible to visualize extradural compression (Figure 4) The filling of an extradural pseudocyst may be difficult and time consuming if the dural defect is small or blocked by a herniated nerve root An extradural contrast lake is suggestive of an extradural pseudocyst (Figure 1)

DISCUSSION

In surveys of operations for disc herniations poor results are reported with frequencies ranging from 7 to 25 per cent (Malmros 1942 Love 1947 O Connell 1951 Guillaume & Janny 1953 Gurdjian et al 1961 Jochheim et al 1961 Nashold & Hrubec 1971) Too much weight should scarcely be attached to these figures as they depend to a great extent on such factors as the selection of the patients the experience of the surgeon and the postoperative treatment However there will always be a reason for a poor result and as stated by Armstrong (1967) most of these conditions are amenable to treatment either surgical or conservative There is far too general a tendency to accept operative failures as irreparable and abandon further treatment whereas in fact most of these patients can be salvaged by appropriate measures

As causes of painful conditions after operations for disc lesions may be mentioned unrecognized lateral herniations (Herlin 1959) bilateral and multiple herniations (Campbell & Whitfield 1947 Armstrong 1951 Greenwood et al 1952 Horwitz & Rizzoli 1967) subsequently occurring herniations root lesions which have arisen during operation or developed on account of long continued root compression root compression caused by ligamentum flavum remnants arthritic changes in the intervertebral joints discitis and infection of other localization in the region may give rise to lumbar pain and radicular symptoms (Armstrong 1951 Knudsen 1963 Pilgaard 1969) Further causes may be arachnoiditis (Hughes 1966) ankylosing spondylitis (De Palma & Rothman 1970) and last but not least psychogenic factors

Extradural cysts are a rare complication of operation for lumbar disc herniation The operative results after closure or excision of the pseudocyst are reported to be good (Pagni et al 1961 Miller & Elder 1968 Rinaldi & Peach 1969 Wilkinson 1971) The formation of an extradural pseudocyst should be prevented by meticulous closure of the dural defect

The patients described in the literature had often undergone one or more operations for lumbar disc herniation (Hyndman & Gerber 1946 Swanson & Fincher 1947 Pagni et al 1961 Shahinfar & Schechter 1966 Miller & Elder 1968 Wilkinson 1971) Epstein (1962) described a case which occurred after repeated lumbar punctures Extradural pseudocysts have also been reported to develop after direct traumata to the lumbar spine (Shapiro & Faske 1950) Incidentally in many cases congenital extradural cysts will remain asymptomatic until a trauma to the region has been sustained (Gortvai 1963)

CONCLUSIONS

The diagnosis of lumbar extradural pseudocyst may occasionally be established on the basis of the history and clinical findings, but a carefully performed myelography with a water-soluble contrast medium will usually be required. Extradural pseudocysts are a rare cause of pain after operation for lumbar disc herniation. However, several investigators claim that they are less rare than suggested by the relatively small number of published cases. The results of surgical treatment of extradural pseudocysts are good. Thus there is every reason to emphasize the importance of myelography in the evaluation of patients with recurrent pain after lumbar disc operation, not only in the demonstration of the presence of a pseudocyst, but also in the disclosure of other of the above mentioned causes of pain.

SUMMARY

Three cases of lumbar extradural pseudocyst which developed after surgery for lumbar disc herniation are reported. The literature on pathogenesis, clinical features and radiographic appearance is briefly reviewed. It is emphasized that the results of surgical treatment of extradural cysts are good. Some other causes of recurrent pain after operation for lumbar disc herniation are mentioned. Myelography is recommended as a useful adjunct in the clarification of the nature of the recurrent pain.

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PROGNOSIS OF ODONTOID FRACTURES

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Accepted 15 ix 72

The occurrence of seven odontoid fractures at Charity Hospital during 1967–68 led us to review our records We surveyed all the charts of patients sustaining cervical vertebral fractures from 1942 at New Orleans Charity Hospital and from 1953 at New Orleans Veterans Administration Hospital From these charts 50 odontoid fractures were found This study was made to ascertain the characteristics complications and prognosis of fractures of the odontoid process

The precise incidence of nonunion of odontoid fractures does not emerge from the literature surveyed Osgood & Lund (1928) stated in their review of the literature that roentgenograms of the end result have been unsatisfactory in the approximately 55 reported patients prior to the report of their patient Review of other studies has not clarified the incidence of nonunion Blockey & Purser (1956) found that 22 of 3) fractured odontoids failed to achieve bony union Amyes & Anderson (1956) stated that only 3 of 58 failed to heal Rogers 1957) reported that 4 of his 9 odontoid fractures developed a non union The total of these series results in a combined nonunion incidence of 28 4 per cent (29/102)

The mortality rate with respect to odontoid fractures has not been definitely ascertained Various studies give contradictory information Osgood & Lund (1928) found that of the 56 patients reported up to that time 29 died a *mortality rate of 52 per cent Amyes & Anderson* (1956) had a mortality rate of only 8 per cent or 5 in 63 Jefferson (1920) had 13 odontoid fractures with an associated atlas fracture Only one of the 13 survived Blockey & Purser (1956) had only one death in their 11 odontoid fractures and this was due to a myocardial infarction more than four years after the accident None of Rogers 9 patients died The total of these series results in a combined mortality rate of 30 9 per cent (47/152)

MATERIAL

The records of 50 patients with odontoid fractures seen at the Charity Hospital from 1942 and the Veterans Administration Hospital from 1953 to June 1968 were analyzed in relation to (1) age and sex (2) mechanism of injury (3) associated injuries (4) type of displacement (5) neurologic complications (6) treatment (7) result and (8) length of follow up

Excluding 9 *patients seen at the Veterans Administration Hospital* the male female ratio in the remaining 41 patients was 9 1

The ages of the patients ranged from 15 to 66 years with the highest incidence occurring in the third and fourth decades (42 per cent)

The mechanism of injury was an auto accident in 62 per cent and a fall in 24 per cent of the patients In all but one patient it was reported that there was direct trauma to the head or face instead of the neck

Other than vertebrae the most commonly associated injuries were mandibular and scapular fractures Four patients had mandibular fractures 3 patients had scapular fractures 3 patients had rib fractures 3 patients had clavicular fractures and 3 patients had ankle fractures One patient had bilateral clavicular and scapular fractures

The odontoid fracture was displaced in 14 patients (28 per cent) The displacement was anterior in 6 patients posterior in 4 patients lateral in 2 patients anterior and lateral in one patient and posterior and lateral in the remaining patient Transient neurologic involvement was seen in 2 patients with displaced fractures The fracture healed in 7 patients and progressed to nonunion in 3 patients One patient had cervical arthrodesis Three patients were lost to subsequent follow up

In our entire series of 50 patients 8 patients developed neurologic complications (16 per cent) Seven of the 8 patients presented initially with neurologic involvement In 4 patients this complication proved temporary 2 patients had permanent neurologic residuals and 1 patient died The odontoid fracture was displaced in 2 of the 8 patients The fracture healed in 4 patients and progressed to nonunion in 2 patients One patient had cervical arthrodesis Four of the 8 patients with neurologic deficits had initial weakness of one or both extremities on one side Two of the 4 were left with permanent weakness Three of the 8 patients had initial paresthesias *all of which were* temporary

TREATMENT

Of our 50 patients 40 were treated conservatively Six were lost to follow up Three had surgical fusions within the first month There was one death due to a respiratory arrest twenty days after the accident

Of the 40 conservatively treated the fracture healed in 32 patients and progressed to nonunion in 8 patients for a nonunion incidence of 20 per cent Three of the 8 nonunions had had no immobilization One patient had 15½ weeks of immobilization after no treatment for the first three days Another patient was immobilized for 14 weeks after a lapse of six months following the accident One had six weeks of immobilization and two had approximately 19 weeks of immobilization Twenty eight of the 32 patients that healed had union in twenty or less (87 5 per cent)

Union was determined by clinical and radiological confirmation One wonders if the two cases that achieved union in 7 and 7½ respectively would have had this diagnosis if laminagrams of the odontoid were done

Seventeen patients on whom the final results are known did not have immediate immobilization Delay in institution of immobilization ranged from two days to seven years Thirteen of the patients went on to bony union All 13 were immobilized within five months after the accident occurred Seven of the 13 were immobilized within one week of the accident one within 10 days one within 15 days one within 4 weeks one within one month one within 3 months and one within 21 weeks There were 4 patients in whom nonunion occurred One had no immobilization for 7 years the second had no immobilization for the first 6 months the third had intermittent immobilization due to the intractability of the patient and the fourth was not immobilized for the first 3 days

The mean for the 32 patients who achieved union was 16 08 weeks of immobilization with a corresponding standard error of 1 2 weeks For these 32 patients upper 90 and 95 per cent tolerance limits were calculated and found to be 25 and 28 weeks respectively These limits indicated that on the average 90 to 95 per cent of all odontoid fractures will heal within the period bounded by the upper 90 and 95 per cent limits under repeated sampling

The length of follow up on the 50 patients ranged from less than a month to 79 months The average time of medical supervision for

these patients was 13 3 months Thirty one patients were followed for less than one year and only 8 had follow up of two years or more

DISCUSSION

The authors were able to review only those charts which had been coded The coding system was started in Charity Hospital in 1942 and in the Veterans Administration Hospital in 1953 We found no odontoid fractures at Charity Hospital prior to 1948 and only two before 1960 at the Veterans Administration Hospital One may conclude that either the coding was improper or the diagnosis was not made The fracture is more common than one realizes but the coding problem (odontoid fractures are coded under fractures of cervical vertebrae) has prevented the collection of a large enough series to have statistical significance

After analyzing the mechanism of injury there is no reason to conclude that blows to the occiput are more common than blows to the face While most agree that posterior displacement of odontoid fractures is rare we had 4 displaced posteriorly and 6 displaced anteriorly Since 62 per cent of the patients were involved in car accidents we would assume that the part of the car involved in the accident would determine whether there was a blow to the face or occiput Therefore we are unable to explain the uniqueness of the posterior displacement in previous series unless we assume that these patients died at the scene of the accident and/or the diagnosis was not made

The authors after analyzing the mechanism of injury are in agreement with Wusthoff s conclusions that injury is to the head or face and not the neck In 49 out of 50 cases it was reported that there was direct trauma to the head or face instead of the neck

From our previous experience it is evident that in order to achieve bony union of an odontoid fracture it must be immobilized Of the 17 patients who did not have immediate immobilization 14 were immobilized within 5 months or less of the accident and 13 of these patients achieved union The results on these patients suggest that whereas immobilization is necessary union can occur even following delayed treatment

Five patients had an operative fusion Three patients were fused soon after the fracture (one month or less) and all went on to union (Figures 1A B C and D) Two patients with nonunion undergoing



A



B



C



D

Figures 1A B C and D Patient no 39 is a [illegible] year old male whose admission x rays (A and B) show anterior and lateral displacement The patient had a posterior C 1 2 3 cervical fusion 2 weeks after sustaining the fracture Figures C and D which show union were taken 8 weeks after surgery



A



B



C



D

fusion attained stability but the odontoid fracture failed to heal (Figures 2A B C and D)

Cervical fusion should involve cervical vertebrae one and two only. Sufficient stability is attained so that a cervical fusion of cervical vertebrae one two and three is not necessary. Cervical fusion is indicated for nonunion of odontoid fractures unstable odontoid fractures immobilized for less than 20 weeks with progressing neurologic deficit and for instability of cervical vertebrae one and two. A relative contraindication to arthrodesis is an ununited fracture which has been immobilized for less than 20 weeks without neurologic deficit

Of the 8 patients who developed nonunion of their fractures 3 had associated major injuries and 5 did not. Their ages at the time of the accident were 16 21 29 53 55 and 66. One of the 8 sustained repeated injuries to his head and neck since the age of 9 and since the diagnosis was not made until the patient was 50 the age at which the fracture occurred cannot be ascertained. From these data we cannot state that age or associated injuries had any bearing on incidence of union

Comparison of the nonunion rate of these fractures with displacement (30 per cent) and those with no displacement (16 7 per cent) shows a higher incidence of nonunion for the displaced fractures

There were 8 patients with neurologic involvement but in only 2 patients was the fracture displaced. It is certainly possible that all of these 8 were initially displaced with 6 being reduced prior to having roentgenograms

A thorough neurologic examination including evaluation of reflexes muscle strength presence or absence of pathologic reflexes and sensation should be done. In addition the quality of respiration should be noted. The neurologic deficit should be initially treated with traction. If sufficient immobilization has not been obtained and the neurologic deficit is progressing cervical arthrodesis is indicated

The main questions still to be answered are How long does it take the fracture to heal and when should one consider doing a fusion?

Figures 2A B C and D Patient no 20 is a 29 year old male whose admission x rays (A and B) show posterior and lateral displacement of the fracture. He was immobilized for 19 weeks with traction and Minerva jacket and then placed in a 4 poster brace for an additional 17 weeks. 36 weeks after the accident he had a posterior C 1 2 3 fusion. Post operatively he was immobilized in a Minerva jacket for 15 ½ weeks. Figures C and D show the fracture site to be ununited



A



B

Figures 3A and B These x rays are of a patient in his 20's who had an undisplaced odontoid fracture. He was treated with 12 days of traction and then placed in a 4 poster neck brace. Figure 3A shows anterior displacement and Figure 3B shows posterior displacement while in the brace.

87.5 per cent of those fractures that achieved union did so within 20 weeks or less. Since our series had a nonunion incidence of 20 per cent, the authors feel that immobilization with traction and/or Minerva jacket for 20 weeks is sufficient to attain bony union if union is going to occur. Since 2 of the 8 nonunions had severe neurologic sequelae, the authors feel that if after 20 weeks of immobilization union has not been achieved cervical fusion is indicated. We have not included as immobilization the wearing of a brace, since this can be removed by the patient and, even if worn, does not provide adequate immobilization as some of the x rays in this article clearly show (Figure 3A and B). For the above reason we have not included brace immobilization when calculating how long the patients were actually immobilized unless the patient was immobilized with only traction and neck brace.

SUMMARY

Tabulation of cases reported in the literature reveal a nonunion rate of 28.4 per cent (29/102) and a mortality rate of 30.9 per cent (47/152) for odontoid fractures.

Analysis of the fifty odontoid fractures in the current series revealed:

1. 42 per cent occurred in the third and fourth decades.
2. 49 of the 50 patients reported direct trauma to the head or face instead of the neck.
3. The most common associated injuries were mandibular and scapular fractures.
4. Displacement of the fracture occurred in 14 patients (28 per cent).
5. Neurologic complications occurred in 8 patients (16 per cent).
6. Nonunion occurred in 8 of the 40 patients treated conservatively (20 per cent).
7. 28 of the 32 fractures (87.5 per cent) that healed with conservative treatment had union in 20 weeks or less.
8. 13 of 17 fractured odontoids which did not have immediate immobilization achieved union.
9. Nonunion rate for displaced odontoid fractures (30 per cent) was higher than for nondisplaced fractures (16.7 per cent).
10. The authors recommend immobilization of odontoid fractures with traction and/or Minerva jacket for 20 weeks. If after 20 weeks of immobilization union has not been achieved, cervical fusion is indicated.

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SUBTROCHANTERIC OSTEOTOMY IN THE TREATMENT OF LEGG CALVÉ PERTHES SYNDROME (L C P S)

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The Legg Calve Perthes Syndrome starts apparently with ischiemia and avascular necrosis of the proximal femoral epiphysis Already in its initial stage the syndrome produces harmful side effects such as hypertrophy of the osteochondral caput (Axer & Schiller 1972) and lateral subluxation (Axer & Schiller 1972 Caffey 1968 Katz 1957 Kemp & Boldero 1966 Korvin 1947 Strange 1965) This combination of biological and mechanical factors disrupts the functional capacity of the hip joint and leads to excessive pressure being exerted by the antero lateral part of the acetabular roof on the corresponding segment of the necrotic femoral head which becomes flattened and "squeezed out laterally and anteriorly This has been observed on plain roentgenograms (Waldenstrom 1934) and on arthrography (Axer & Schiller 1972) in the initial stage of L C P S

Consequently treatment should be directed towards early correction of this mechanical derangement of the hip joint by placing the diseased femoral head deeply into the acetabulum To thereby reduce the femoral head internal rotation combined with abduction is necessary This will accomplish a more even redistribution of the intra articular pressure over the articular surface of the femoral head Many methods of conservative treatment with and without weight bearing have been devised to obtain this goal (Goff 1954 Katz 1967 Harrison & Menon 1966 Harrison et al 1969 Tachdjian & Jouett 1968 Petrie &

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Bitenc 1971). All these methods of conservative treatment impose prolonged physical restriction on the child.

Innominate osteotomy (Salter 1966) has been used to provide acetabular coverage but its application has been limited to patients with a poor prognosis (Bobechko et al. 1968).

We prefer varus derotation subtrochanteric osteotomy (Axer 1965) to the above methods for the following reasons:

1. Following the operation the treatment can usually be completed in six to eight weeks in a double hip spica after which the child is free to bear weight without restriction while healing takes place. This greatly relieves the physical restriction which awkward devices place on the child and the psychological burden on the parents and the child.

2. The proper amount of internal rotation and abduction of the proximal fragment can be determined by preoperative radiography in different positions of the hip and by arthrography; the operative technique is simple.

3. The osteotomy produces hyperaemia in the hip joint area such as that seen after fractures (Laurnen & Kelly 1969, Mindell & Sherman 1951, Wray 1964). This biological effect together with the normal pumping action of the unrestricted pelvi-femoral muscles may accelerate revascularisation of the epiphysis and in this way decrease the time of the disease process (Axer & Rzetelny 1971). It may also stimulate the growth in length of the extremity (Siffert 1966, Sofield 1959) to compensate for its shortening which is the natural sequela of L.C.P.S. (Carpenter & Powell 1960, Edgren 1965). Furthermore the normal range of motion will permit the reciprocal moulding of the plastic femoral head and of the acetabulum.

4. Finally, and not least of all, after postoperative treatment is completed the surgeon need not rely on the fortitude and intelligence of the parents to continue with adequate and consistent care of the unruly youngsters. All that is required are regular x-ray checks of their hips.

MATERIAL AND METHODS

Between 1958 and 1971 subtrochanteric varus and/or derotation osteotomy was carried out in 51 hips (47 patients with L.C.P.S.) in our department. This study is based on osteotomies performed between the years 1958–1970 in 31 patients with unilateral L.C.P.S. whose

average age at the onset of the disease was six years The latter was estimated from the earliest available radiograph of each patient according to Stahl s (1944) method We have been inclined however to antedate the commencement of the disease in patients whose earliest radiographs revealed a stage of advanced condensation of the femoral epiphysis for longer periods of time than Stahl estimated (up to one year)

In 23 patients a varus derotation was performed in 9 derotation and in 2 patients varus osteotomy Five patients were reoperated Thus a total of 39 osteotomies were done 26 patients were males and 8 females

Prior to the operation most patients had some form of consistent conservative treatment which lasted from one to twelve months

The Operation

There has been little change in the technique since 1965 (Axer 1965) and this will not be repeated Anteversion views (Dunlap et al 1953) are made pre operatively to prevent excessive derotation and hence retroversion especially in the early stages of the disease when the incidence of increased anteversion is low (Axer et al 1972) Arthrography of both hips is routinely performed under anaesthesia with the hips in different positions including that of internal rotation and abduction in order to estimate the degree of flattening of the osteochondral caput and to select more accurately the degree of derotation and varus angulation required to effect satisfactory coverage The bone plate is pre bent to the desired angle and fixed to the femoral shaft with four screws after excision of a suitable wedge of bone with the base pointing medially

Method of Evaluation of Results

In studying the results of treatment we have utilized the method of Mose (1964) employing the transparent device described by Edgren (1965) Good results comprised spherical heads whose radii were equal on antero posterior and lateral radiographs (All lateral views of the hips were made in Lauenstein s position) Fair results had heads which deviated from a circle by up to 2 mm Poor results had heads which were irregular with outlines differing by more than 2 mm Although this system does not take into account the relationship between the head and the acetabulum it gives a very critical analysis of the anatomical outcome of the disease and is of considerable prog

nostic value since sphericity of the femoral head appears to be of paramount importance for the functional durability of the hip joint (Edgren 1965 Heyman & Herndon 1950 Katz 1967 Meyer 1966 Mose 1964 Sundt 1949)

In the preliminary report (Axer 1965) the results were assessed on the basis of the comprehensive quotient of Heyman & Herndon (1950) It has been shown that it is difficult to measure accurately the head neck quotient and that it can vary significantly with hip rotation (Schiller & Axer 1972) Thus the comprehensive quotient even in the early period of healing has been said to be unduly flattering (Harrison et al 1969) Aside from the head neck quotient the other individual quotients are quite reproducible and stable (Schiller & Axer 1972) and very useful for describing various important facets of the disease i e epiphyseal flattening (epiphyseal quotient) acetabular capacity (acetabular quotient) and the degree of lateral protrusion of the head (acetabular head quotient)

We have calculated the comprehensive quotients in the previously reported 11 cases for comparison

RESULTS

The final results in all 34 patients based on the method of Mose are presented in Table 1 after an average follow up of 6 years and 8 months (from a minimum of two years to a maximum of 13 years and ten months[1]) At the last roentgenological examination all involved hips were either completely healed (18 hips) or they were in the late stages of regeneration (16 hips) The shape of the head at the advanced stage of healing is usually preserved until adulthood (Jonsäter 1953 Trueta & Trias 1961) We have observed improvement of the shape of the femoral head in a considerable number of patients after the second post-operative year (Axer & Rzetelny 1971 Figure 7A B C, D)

Table 1 Final Results in 34 Unilateral Cases According to Mose

Result	No of cases	Percent
Good	18	53
Fair	13	38
Poor	3	9

[1] Of the 29 patients reported previously (Schiller & Axer 1972) 2 cases with poor results improved during the last year and became fair

Table 2 Comprehensive Quotient in the 11 Cases of the Earlier Report

Year	Very good	Good	Fair	Poor	Average duration of postoperative follow up (in years)
1965	5	4	1	1	2 5/12
1971	7	2	1	1	8 3/12

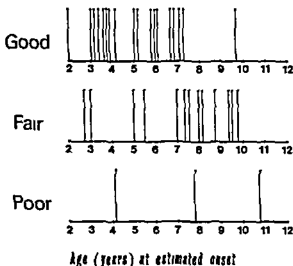


Figure 1 Graph showing relation between age at estimated onset of the disease and the anatomical end results (Mose) (see text)

Results in the initial 11 patients with reported comprehensive quotients are presented in Table 2 After an average additional period of 5 years of observation (average follow up 8 years and 3 months) they have remained either unchanged or became upgraded from good to very good (3 cases) One case dropped from very good to good

Table 3 Results According to the Stage of the Disease at the Operation (Mose)

Result	Necrosis	"Fragmentation"	Regeneration"
Good	9	9	0
Fair	4	3	6
Poor	1	0	2
Total	14	12	8



Figure 2 Patient N E male aged 9 years and 9 months at estimated onset of the disease

Figure 2 A Antero posterior preoperative roentgenogram at the age of 11 years and 8 months showing the regeneration stage with marked lateral protrusion of the head 11 mm increase in the medial joint space marked epiphyseal flattening and metaphyseal cystic changes

The Results in Relation to the Age at Onset (Figure 1)

Good results were concentrated among children with onset of the disease between the third and the seventh year of life Most of the fair results were encountered in patients who became affected between the seventh and tenth year of life

The average age at onset in patients with good results was 5 years with fair results it was 7 years and with poor results it was 7 years and 6 months In 19 of the 31 patients with good and fair results the disease began before they reached the age of 7

Results According to the Stage of the Disease at Operation (Table 3)

Best results were obtained in the 24 hips operated in the stage of necrosis or fragmentation None of the 8 children operated in the stage of regeneration ended up with a good result 6 of them became "fair and two poor



Figure 2 B Antero posterior roentgenogram 7 months after a varus derotation sub trochanteric osteotomy shows enlarged head well reduced within the acetabulum The greater trochanter is very high This patient later had a transfer of greater trochanter Articulo trochanteric distance 2 mm

Results according to the Type of Osteotomy

1 Twenty three patients had derotation varus osteotomy initially 12 became good 10 fair and one became a poor result The latter was a boy aged 9 years and 9 months at the estimated onset of the disease who had no treatment until he was 11 years and 8 months old when surgery was performed on a subluxated hip with a hypertrophied caput and in the stage of regeneration (Figure 2A B C)

An example of a good result is illustrated in Figure 3A B C and D[2] with a follow up of 10 years and 9 months and of a fair result in Figure 4A B C with a follow up of 4 years and 7 months

Three of the 23 patients had the varus derotation osteotomy re peated (Table 4) In one of them (case no 1) the plate broke after the first operation subluxation recurred and the acetabulum head quo tient became very low (65 per cent) One year later when the hip was

[2] The patient s radiographs were presented in the preliminary report (Axer 1965) p 497 case 3 with a follow up of 3 years and 7 months



Figure 2 C Lateral roentgenogram 2 years after surgery at age of 13 years and 7 months A poor result (Mose) with enlarged head

Table

No	Kind of operation		Age at operation			
	First	Reoperation	First		Reoperation	
			Y	M	Y	M
1	Varus/ Derotation	Varus/ Derotation	5	7	6	7
2	Varus/ Derotation	Varus/ Derotation	4	10	6	3
3	Varus Derotation	Varus/ Derotation	9	9	11	2
4	Varus	Derotation	6	1	8	6
5	Derotation	Varus	9	4	10	8



Figure 3 Patient S M male aged 6 years and 8 months at estimated cnset of the disease and treated conservatively for 8 months prior to surgery

Figure 3 A Antero posterior preoperative roentgenogram at the age of 7 years and 9 months showing the necrotic stage with some epiphyseal flattening and en larged medial joint spa e Cystic damage beneath the somewhat irregular growth plate is present

'eoperation

Stage at operation		Indications for reoperation	Results	
First	Reoperation		First	Reoperation
Necrosis	Regeneration	Recurrence of subluxation due to broken plate	Fair	Good
Fragmentation	Regeneration	Recurrent subluxation	Fair	Fair
Necrosis	Regeneration	Recurrent subluxation	Poor	I oor
Regeneration	Regeneration	Insufficient c iverage of fem ral head	P or	Poor
Necrosis	Fragmentation	I ecurrent sul luxati n	I r	Fair



Figure 3B Antero posterior roentgenogram 4 months after a rather low varus derotation subtrochanteric osteotomy shows a well centered caput with the epiphysis already in the regeneration stage The osteotomy angle was 29

in the early regeneration stage the second osteotomy was done This hip eventually became a good result

In another child (case no 2) following the osteotomy inadequate coverage of the femoral head was obtained (acetabulum head quotient 75 per cent) The second derotation varus osteotomy was carried out in the regeneration stage and a satisfactory coverage (acetabulum head quotient 94 per cent) with a fair result was achieved

The third patient (case no 3) had a recurrence of subluxation with a poor result which did not improve after reoperation carried out in the stage of regeneration

2 Two patients had varus osteotomy alone Both became poor results The first patient was a girl with an estimated onset of the disease at the age of 4 She was treated in another hospital with a weight relieving calliper for over a year At the time of surgery she was 6 years old and the head of femur was already in the regeneration

Figure 3C and 3D Antero-posterior and lateral roentgenograms 10 years and 3 months after surgery showing "good" result (Mose) The post-cast of my angle is now 8 Note head sizes are equal



Figure 4 Patient O L, female aged 7 at time of estimated onset who was treated conservatively for 14 months

Figure 4 A Antero posterior preoperative roentgenogram at age 8 years and 7 months showing the regeneration stage with marked lateral protrusion of the head 5 mm increase in the medial joint space marked head hypertrophy (8 mm in radius greater) and marked flattening of the epiphysis

stage with considerable flattening and subluxation No internal rotation could be achieved and in spite of varus angulation of 30 inadequate coverage was obtained (acetabulum head quotient 79 per cent) Therefore the second osteotomy (derotation) was carried out in the late stage of regeneration (Table 4, case no 4) Although the head was finally well seated (acetablum head quotient 100 per cent) the result remained poor (Figure 5)

The other patient was a boy aged 11 at the estimated onset of the disease After an uncooperative 6 months in a spica he was lost to treatment for 8 months At the operation he was 12 years and 2 months old and with a markedly deformed and subluxated hip in the stage of regeneration He had a limp with severe pain and limitation of motion in the hip Varus osteotomy was done as a salvage procedure it resulted in relief from pain but it was the worst result in the series



Figure 4 B Antero posterior roentgenogram 2 years and 7 months after surgery showing good coverage but an A T D of minus 7 mm and premature closure of the epiphyseal plate

3 Nine patients had derotation osteotomy alone 6 of them achieved a good and 3 a fair result One of them improved from poor to fair following reoperation (varus osteotomy) which was performed 1 year and 4 months following the first operation in the stage of fragmentation (Table 4 case no 5)

An example of a good result can be seen in Figure 6A B[3] C after 13 years and 10 months of observation at the age of 21 years

Reoperations

Four patients were in the regeneration stage at the time of the second operation and one in the stage of fragmentation The indication for reoperation was insufficient containment of the femoral head caused either by recurrence of subluxation or by inadequate initial coverage of the head at the first operation In 3 patients the result did not change In 2 they improved in one from fair to good and in the other one from poor to fair

[3] Radiographs of this patient were presented in the preliminary report (Axer 1965) case 1 p 495 with a follow up of 5 years and 4 months



Figure 4 C Antero posterior roentgenogram 9 months after distal transfer of the greater trochanter Trendelenburg sign disappeared Note the marked head hyper trophy (10 mm in radius greater than the contralateral side) The head is spherical This is a fair result (Mose)

Ancillary Surgery

One patient with a fair result had adductor tenotomy 3 patients had trochanteric epiphysiodesis with distal transfer of the hip ab ductors 3 patients had transfer of the greater trochanter distally (Figure 4C) and curettage of its epiphyseal plate Thus 6 of the 34 patients had surgery to their abductor mechanism

The indications for this ancillary surgery have been Trendelenburg limp with the tip of the greater trochanter approaching or crossing the level of the apex of the femoral head (negative articulo trochante ric distance of Edgren (1965))

It was found that muscle strength improved the limp and the Trendelenburg sign disappeared after these operations but in the 3 patients with trochanteric epiphysiodesis the greater trochanter con tinued to grow significantly



Figure 5 Patient Z M a female aged 4 years and 2 months at time of estimated onset of disease At the age 6½ years in the regeneration stage of the disease she had a varus osteotomy after 15 months of conservative treatment No internal rotation was possible at the time of surgery Derotation osteotomy was done at the age of 8 years and 4 months to decrease the still present anteversion and to correct the persistent poor coverage of the head This antero posterior roentgenogram shows the very high trochanter (articulo trochanteric distance 22 mm) and the irregular head A poor' result

Complications

In one patient the plate broke during the early postoperative period This resulted in a loss of containment of the femoral head (see above) There were no other postoperative complications

Post Osteotomy Angle

This angle was measured by constructing intersecting lines through the middle of the proximal and distal fragments of the osteotomised shaft of the femur This is a labile measurement easily affected by rotation of the femur but the appearance of the metallic plate has been a useful guide to the estimation of the actual position of the extremity from one examination to another

The average post osteotomy angle in the 23 cases with varus angulation seen immediately after surgery was 16 with a range of 7 to 35



Figure 4 C Antero posterior roentgenogram 9 months after distal transfer of the greater trochanter Trendelenburg sign disappeared Note the marked head hyper trophy (10 mm in radius greater than the contralateral side) The head is spherical This is a 'fair' result (Mose)

Ancillary Surgery

One patient with a fair result had adductor tenotomy 3 patients had trochanteric epiphysiodesis with distal transfer of the hip ab ductors 3 patients had transfer of the greater trochanter distally (Figure 4C) and curettage of its epiphyseal plate Thus 6 of the 34 patients had surgery to their abductor mechanism

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It was found that muscle strength improved the limp and the Trendelenburg sign disappeared after these operations but in the 3 patients with trochanteric epiphysiodesis the greater trochanter con tinued to grow significantly



Figure 7 A

Figure 7 S S a female aged 8 years and 2 months at estimated onset At the age of 9 years and 3 months following one month of bed rest derotation sub trochanteric osteotomy was done when the head was in the necrotic stage

Figure 7 A and 7 B Antero posterior and lateral roentgenograms 2 years after surgery showing late regeneration stage in a head well contained within the acetabulum However on the lateral view it is not round and more than 2 mm of irregularity exists Thus it is an early poor result

and at final analysis of 21 cases it decreased to an average of 11 5 with a range of 0 to 25

Clinical Assessment

Several patients complained of mild sporadic hip and thigh pain 8 patients limped and 10 had a positive Trendelenburg sign 18 patients had shortening of the affected extremity by an average of 1 4 cm (ranging from 0 5 to 4 5 cm) The patient with a length discrepancy of 4 5 cm had a poor result and a fixed hip contracture in flexion and external rotation In 4 patients the operated extremity became longer by 1 to 2 cm Most of the patients exhibited some limitation of internal rotation abduction or external rotation



Figure 7 B

DISCUSSION

It has been observed in the past that the clinical assessment of results for up to 10 and 15 years after healing of L C P S shows little correlation with the roentgenographic appearance of the diseased hip joint (Broder 1958 Evans 1958 Eyre Brook 1936 Meyer 1966 Mindell et al 1951) Twenty five years or more after healing the spherical hips present little roentgenographic or clinical evidence of degenerative arthritis but the latter begins to occur with increasing frequency and severity in hips which healed with deformity (Branciforti & Montina 1964 Danielsson & Hernborg 1965 Eaton 1967 Gower & Johnston 1971 Helbo 1966 Ratliff 1956 Sundt 1949) It seems reasonable to assume that the hips which are not as close to normal as the good or fair groups of Mose are potential candidates for this disease In this series of 34 patients 53 per cent had good 38 per cent fair and 9 per cent had poor results (Table 1) Hence 91 per cent were satisfactory and 9 per cent unsatisfactory

When compared with larger series of conservatively treated patients exposed to prolonged physical restriction (Katz 1967 Mose 1964 Petrie & Bitenc 1971) and assessed according to the method of Mose the

Figure 7C and 7D Antero posterior and lateral roentgenograms 3 years and 1 month after surgery Late regeneration stage The head is now more circular The result improved from poor to fair during the third postoperative year



Figure 7 B

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When compared with larger series of conservatively treated patients exposed to prolonged physical restriction (Katz 1967 Mose 1964 Petrie & Bitenc 1971) and assessed according to the method of Mose the

Chung & Moe (1965) did not find a statistically significant correlation between these two factors In this study differences within the groups do exist we found that 15 out of 18 children with good results contracted the disease before the age of 7 whereas of the 13 children with fair results only 4 were less than 7 years old at the time of its estimated onset (Figure 1)

Varus angulation osteotomy alone may not be adequate Two patients who had this procedure ended up with poor results

With derotation osteotomy alone good anatomical results were achieved in 6 out of 9 patients 3 had a fair result Although the incidence of good results following varus derotation osteotomy was lower (12 out of 23) we prefer this operation to derotation osteotomy because it seems to be more efficient in achievement of optimal containment of the head

Not included in this study are 17 additional osteotomies with a postoperative follow up of less than two years With few exceptions their progress has been very gratifying

It has been generally recognised that hips with so called partial involvement of the capital epiphysis carry a better prognosis especially those who became affected with L C P S very early in life Some of them may heal with spherical femoral heads even without treatment However the establishment of the degree of the involvement of the femoral epiphysis is possible only in the later stages of fragmentation We realise that some of our patients operated on in the initial stage of the disease may have had a partial involvement but we feel that an undue delay of this simple operation would be hardly justified in children over four years of age with an established diagnosis of L C P S because an opportunity of achieving a spherical head with minimum physical restriction of the child may be missed

If following the osteotomy the subluxation recurs the operation should be repeated as soon as possible In 2 out of the 5 reoperated patients improvement of the shape of the femoral head was observed

Transfer of the greater trochanter in the presence of a negative articulo-trochanteric distance accompanied by abductor limp is a useful ancillary procedure Curettage of the trochanteric growth plate may not be sufficient for correction of this deformity as the greater trochanter continues to grow The experimental findings of Salenius & Videman (1970) provide an explanation for this phenomenon

In spite of the varus osteotomy the shortening of the operated extremity was found in only 18 patients and it amounted to an average

of 1 4 cm This amount of shortening can be expected to develop as a natural sequela of L C P S independently of the method of treatment The improvement of the initial postoperative leg length discrepancy was due, most probably to the stimulation of enchondral ossification caused by hyperaemia following the osteotomy and to the progressive increase of the post osteotomy angle

SUMMARY AND CONCLUSIONS

1 This study is based on an analysis of results of subtrochanteric osteotomy carried out in 34 patients affected with unilateral L C P S between 1958 and 1970 Five reoperations were performed The average postoperative follow up was 6 years and 8 months ranging from a minimum of 2 to a maximum of 13 years and 10 months
2 The principles underlying this procedure are described Its main advantage is the marked shortening of the time of physical restriction imposed upon the child compared with different methods of conservative treatment
3 There were 18 (53 per cent) good 13 (38 per cent) fair and 3 (9 per cent) bad results according to Mose s method of evaluation of anatomical results When the 8 patients operated in the late stage of the disease are eliminated, the results are good and fair in 25 patients and poor in one Best results were obtained when the operation was carried out at the early stages of the disease and in children who became affected before the seventh year of life These results compare very favourably with larger series of patients treated conservatively for prolonged periods of time
4 The 11 patients of the first communication (Axer 1965) have been found to maintain and in three instances to improve their previously reported comprehensive quotient after a further period of observation averaging 5 years In one of them a very good result became good
5 Average shortening of the operated extremity amounted to only 1 4 cm

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of 1 4 cm This amount of shortening can be expected to develop as a natural sequela of L C P S independently of the method of treat ment The improvement of the initial postoperative leg length dis crepancy was due most probably to the stimulation of enchondral ossification caused by hyperaemia following the osteotomy and to the progressive increase of the post osteotomy angle

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THE FIXATION OF EXPERIMENTAL FEMORAL SHAFT TORQUE FRACTURES

M J S Hubbard

Accepted 9 x 72

Spiral fracture of the shaft of the femur often occur in the elderly and their internal fixation presents a difficult problem (Roberts 1962) The following experiments show how spiral fractures may be produced by torque in the cadaver and how different methods of internal fixation withstand torque stress

METHODS

Twenty fresh cadaveric femora were subjected to 4 consecutive tests each

1 *Breaking Torque* The femur was held in the specially moulded vice of the Avery" torque testing machine by the middle and upper thirds so that 15 0 cm of shaft remained free between the distal edge of the vice clamp and the adductor tubercle The other torque vice of the machine was then applied to the intercondylar areas anteriorly and posteriorly and tightened This position of the torque vice clamp was chosen so that the length of the fracture would not exceed 10 cm Above this length plating would have been diff cult (Figure 1)

A torque moment was then applied and the minimum torque generated to break the femur was recorded from the torque testing machine graph.

The 20 fractures produced were all spiral in type and had a longitudinal length of between 7 5 cm and 10 0 cm (mean 8 1 cm) All extended to within 5 0 cm of the level of the adductor tubercle

2 *Minimum Torque after Kuntscher Nail Fixation* The largest available nail of 15 mm in stainless steel was used to negotiate the proximal shaft fragment after reaming The minimal distal medullary diameter was 16 mm The nail was introduced into the cancellous bone of the distal fragment Test 1 was repeated and the min mum torque moment recorded. There was no further damage to any of the bones during the second test The large minimal distal diameter resulted from the proximity (5 cm) to the adductor tubercle

3 *Minimum Torque after Double Plate Fixation* The Kuntscher nail was then withdrawn and the fracture fixed using two Muller compress on plates One 8 hole and one 6 hole plate with a total of 10 screws were inserted Five 7 5 am screws were placed in the distal fragment (Figure 2) Attempts at compression caused

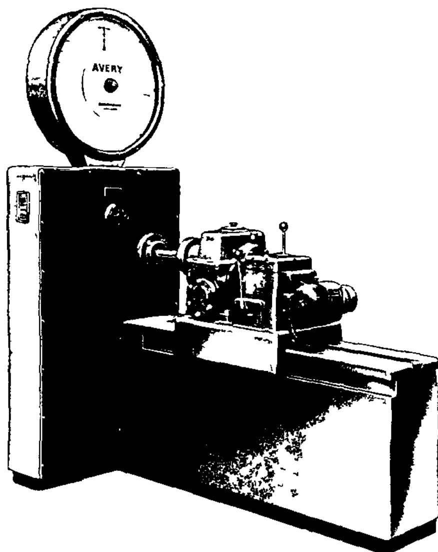


Figure 1 The avery torque testing machine

comminution at the fracture site The torque test was performed as before some secondary fractures occurred at the screw holes The plates and screws were then removed

4 *Minimum Torque after Kuntscher Nail and Cement Fixation* After reaming the distal fragment 80 g of slow setting methylmethacrylate cement (Simplex C.) were prepared When of doughy consistency they were introduced by a punch into the medullary canal of the distal fragment away from the fracture site The same

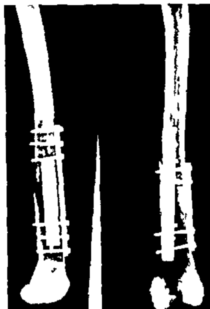


Figure 2 Double compression plate fixation of a spiral fracture of the shaft of a cadaveric femur
Compression screws were used throughout and five were placed in the distal fragment

Kuntscher (15 cm) was inserted The cement was allowed to set for 20 min and the torque test repeated The minimum Torque generated was recorded

RESULTS

These figures are given in the graph in Figure 3 and in Table 1

Test 1 The breaking torque was inversely proportional to age with males slightly stronger than females in the younger age groups The type of fractures produced were remarkably uniform (Figure 3) (Lindahl 1968)

Test 2 The Kuntscher nail was never able to obtain a firm grip of the distal fragment and the low values recorded confirm this (Table 1)

Test 3 The failure of this form of fixation was caused by the distal screws cutting through the softer bones of the distal fragment Compression and fixation of the spiral fracture also proved difficult The poor hold the compression screws obtained on the distal cortex made the final strength of compression small (Table 1)

Since the plates and screws in all tests remained completely unbent and undamaged the failure could not be attributed to them The absence of a well developed cortex in the distal third was an important factor

Table 1 Breaking torque moment Adult femur shafts in kilogram centimeters

Number	Age	Sex	Normal femora	Kuntscher nail fixation	Compression double plate fixation	Kuntscher nail & acrylic fixation
1	50	♂	1064	11 5	40	200
2	53	♀	665	19 5	66	200
3	19	♂	3225	19 5	80	132
4	67	♂	532	20 0	52	132
5	67	♀	495	20 0	46	528
6	71	♂	532	26 0	36	200
7	68	♀	505	13 0	42	205
8	70	♀	532	13 0	58	200
9	22	♀	1264	20 0	46	264
10	48	♂	798	31 0	42	132
11	61	♂	1011	19 5	78	132
12	26	♂	1330	6 5	75	200
13	52	♂	1064	19 5	57	140
14	53	♀	851	31 0	62	200
15	50	♀	798	20 0	72	180
16	68	♀	532	13 0	40	2[illegible]0
17	70	♀	495	20 0	47	2[illegible]0
18	72	♀	495	13 0	57	140
19	76	♀	505	20 0	52	200
20	80	♂	528	19 5	70	2[illegible]0

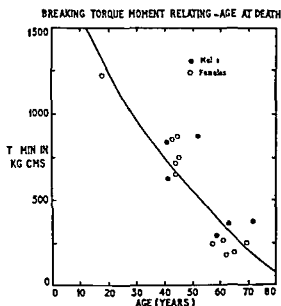


Figure 3

Test 4 The failure point coincided with the fracture of the plastic at the fracture site The nail still remained embedded in the plastic in the distal fragment after this point (Table 1)

DISCUSSION

As a torque moment produced spiral oblique fractures in the cadaveric femur on every occasion it is very probable that similar forces produce them in life (Perkins 1956) The minimum breaking torque generated is a useful comparison of the strength of the methods used for fixation

From a mechanical point of view a Kuntscher nail alone is quite unsuitable Nail and cement or plates and screws may be useful forms of fixation of oblique shaft fractures as long as non weight bearing is adhered to until union is complete Nail and cement can be used in spiral fractures longer than 10 0 cm when plating becomes difficult Even on the shorter fractures of the lower third nail and cement is the strongest fixation available although compression plates and screws have produced excellent clinical results (Slatis 1971)

Although 20 mm Kuntscher nails are now available and their strength increases as the fourth power of their radius the massive reaming may reduce the cortex by half (Clawson 1971) Previous reports of double plates versus the 11 mm Kuntscher nail in the femur showed the latter had no fixation (Lindahl 1965) Sintered fibre attachments for similar femoral implants have been found to be only one fifth as strong as the acrylic bond (Galente 1971) Ceramic bonds were only one fiftieth the strength of the acrylic bond (Welsh 1971)

Attempts at placing screws through or around a slotted nail are technically difficult and secondary screw hole fractures remain a problem (Charnley 1970)

Before acrylic cement can be recommended for use in human fracture fixation more must be known of its effects on callus Early work (Wiltse 1957) showed periosteal callus should bridge a 2 gap filled by acrylic cement in the monkey femur Endosteal callus and remodelling appeared reduced by the mere physical presence of the cement rather than by a cytotoxic effect

Nail and acrylic has been used for fractures through metastases (Singh 1966) when union by bone is not an important consideration Large quantities (40 g) of intramedullary cement do not appear to prevent per-operative sub-trochanteric fractures from uniting in total

hip replacement patients (Charnley 1970) Initial reports of the fixation of per trochanteric fractures of the femur with nail plate and cement were favourable (Scheuba 1969) but the late complications of infection and re fracture attributed to inadequate callus have resulted in the cessation of this method (Scheuba 1970) The present technique places the cement distally away from the fracture site so as to fix the nail distally without interrupting the callus formation With this modification nail and cement should now be tested in animals before its limited use in elderly humans with spiral fractures can be advocated

SUMMARY

1 The minimum torque generated in experimental fractures of the femoral shaft is described
2 The same fractures were fixed consecutively with Kuntscher nail double compression plates and Kuntscher nail and cement and were similarly tested in torque
3 Possible use of nail and cement to fix torque fractures are discussed

ACKNOWLEDGEMENT

My thanks are due to Rolls Royce Limited Crewe for technical facilities for this research to the Department of Pathology of Crewe Memorial Hospital and the Kent & Canterbury Hospital for specimens and to North Hill Plastics for their supply of the acrylic cement

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Figure 1



Figure 2



Figure 3

At operation the popliteal artery was exposed through an S shaped incision in the popliteal fossa. The aneurysm measured 1½ cm in diameter and arose from the posterior aspect of the popliteal artery in the midline No abnormality was detected in the posterior capsule of the knee joint nor in the other contents of the popliteal fossa The aneurysm was mobilised and the artery clamped above and below The aneurysm was excised and the resultant arteriotomy repaired with 6/0 silk. Inspection of the specimen showed some evidence of old organized thrombus in the wall of the aneurysm

The wound healed by first intention and when mobilised he was given a tapered raise to the heel of the shoe to reduce the extension strain of the knee when walking Two months after the operation when he stood without the heel raise there was only minimal recurvatum possibly due to fibrosis associated with the scar in the popliteal fossa

DISCUSSION

Popliteal aneurysm is an uncommon condition There were only 10 *cases reported in the British literature in the 11 years before 1946* and in review of a 26 year period between 1938 and 1964 Baird et al (1966) recorded only 61 cases from the total inpatient turnover of the Toronto General and Western Hospitals The largest recorded series is of 233 popliteal aneurysms seen between 1961 and 1968 in the Mayo Clinic (Wychulis et al 1970)

Aetiology of popliteal aneurysms is now almost entirely atherosclerotic 84 per cent of Baird s series and 99 per cent of Wychulis series Of the rarer causes syphilis used to be a common aetiological factor but much less so of recent years trauma either direct or indirect (as during menisectomy) and mycosis make up the remainder

As to the mode of presentation intermittent claudication is the most common presenting symptom others being pain and swelling in the popliteal fossa symptoms of popliteal nerve compression, ankle swelling and incipient gangrene of the foot Thrombosis and distal embolism always represent the greatest threat to the viability of the limb and even in larger atherosclerotic aneurysms rupture is an uncommon event (occurring in 8 per cent of Baird s series)

In the case described the symptoms of intermittent claudication were probably due to obstruction of the popliteal artery in the fully extended position of the knee microembolic phenomena may have been a contributing factor considering the fact that at presentation neither the posterior tibial nor the dorsalis pedis pulses were palpable and at operation there was evidence of organised thrombus in the wall of the aneurysm As to the aetiology the aneurysm is probably secondary to trauma of the arterial wall as a direct result of the genu recurvatum

CONCLUSION

A case of popliteal aneurysm in association with genu recurvatum is *described and a causal relationship suggested*

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AGE AND SEX INCIDENCE OF OSTEOPHYTES IN THE KNEE JOINT

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Accepted 9 x 72

Periarticular osteophytes have been considered to be an early sign of osteoarthritis However Danielsson (1964) found that osteophytes in the hip joint rarely developed into osteoarthritis of the hip Daniels son & Hernborg (1970) demonstrated that only about one third of the individuals with radiographically evident osteophytes in the knee joint later on developed osteoarthritis with structural changes in the joint

Jacqueline et al (1950) and Jacqueline & Veraguth (1954) stated that osteophytes in the hip were related to the process of aging similarly Hernborg & Nilsson (1972) found that osteophytes in the knee joint tended to grow with age This paper will try to describe the age and sex specific incidence of osteophytes in a randomly selected population

MATERIALS AND METHODS

In the archives of the Department of Radiology General Hospital Malmo 1179 radiograms of knee joints were studied The radiograms had all been obtained for reasons other than knee symptoms

Venographies In 315 men and 311 women obtained mainly for the diagnosis of thrombosis

Arteriographies In 169 men and 139 women obtained mainly for the diagnosis of arterial occlusion

Cancer control In 345 women obtained exclusively in the routine search for metastases after operation for carcinoma of the breast as part of the follow up program in the hospital

In all the films the presence or absence of definite osteophytes was noted

RESULTS

At first the homogeneity of the radiographic material was evaluated. It was found that the incidence of osteophytes in men was higher in individuals in whom the knee radiogram had been taken in conjunction with an arteriography as compared to the venography cases (Table 1). In women no such significant differences could be demonstrated between the three groups: arteriography, venography and cancer. The arteriography cases were excluded from the calculations of incidence in men. In Table 2 the age and sex specific incidences of osteophytes are shown in 10 year age groups for men and women separately. Before the age of 50 osteophytes were rarely found; after 60 there was a considerable increase in women, and after 70 more than one third had osteophytes. The incidence in old men did not approach that of old women; if the arteriography cases were included the difference between men and women, however, became less pronounced.

Table 1. Comparison between the incidence of osteophytes in arteriographies and venographies in men

	Arteriography	Venography
30–39	0/4	0/4
40–49	2/27	0/32
50–59	6/66	3/49
60–69	13/37	3/113
70–79	7/30	5/88
≧ 80	4/5	1/29

Table 2. Age and sex specific incidence of osteophytes

	Total no of joints	Fraction with osteophytes Men	Women
30–39	9	0.00	0.00
40–49	177	0.00	0.04
50–59	232	0.06	0.04
60–69	304	0.03	0.18
70–79	218	0.06	0.35
≧ 80	70	0.03	0.37

DISCUSSION

The difference between the two groups of men implies that data obtained in this manner cannot be accepted without criticism as a random sample of the population The difference is not readily explained but it may be suspected that the presence of osteophytes as well as symptoms from the lower limbs which cause an arteriography to be made, usually arteriosclerosis are both closely linked to the biological age of the individuals and that this link in women is not sufficiently strong to penetrate in these data The difference in the *incidence of osteophytes between old men and old women is also* unexplained It is however known that osteoarthritis of the knee including obliteration of the joint space and periarticular structural changes is more common in women than in men (Danielsson & Hernborg 1970)

SUMMARY

In 1 179 radiograms of knee joints obtained for reasons other than knee symptoms, the presence or absence of periarticular osteophytes was recorded The incidence of osteophytes increased with age and more in women than in men Because of the selection of films the calculated incidence may not without criticism be accepted as equal to that of a random sample of the population

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THE RELATIONSHIP BETWEEN OSTEOPHYTES IN THE KNEE JOINT, OSTEOARTHRITIS AND AGING

JERKER HERNBORG & BO E NILSSON

Accepted 9.x 72

Danielsson (1964) demonstrated that osteophytes on the articular edges of the hip joint are not related to the clinical entity of osteoarthritis of the hip which includes narrowing of the joint space and juxta articular structural changes Jacqueline et al (1950) and Jacqueline & Veraguth (1954) stated that osteophytes in the hip rather relate to the process of aging Ahlback (1968) in a radiographical study of osteoarthritis of the knee joint found that osteophytes increased with increasing obliteration of the joint space Danielsson & Hernborg (1970) found that only about one third of the individuals with radiographically obvious osteophytes in the knee joint later in life developed osteoarthritis with structural changes The objective of the present investigation was to study the relationship of osteophytes in the knee joint aging and osteoarthritis

MATERIAL AND METHODS

176 knee joints sampled in the archives of the Roentgen Diagnostic Department Malmö in which radiographical evidence of osteophyte formation had been present during the years 1950–1958 were re investigated in 1968 According to the outcome of the two investigations the patients were divided into three groups

Group I 52 knee joints with osteophytes only in the initial radiogram in which structural changes had not developed during the follow up

Group II 34 joints with osteophytes only in the initial radiogram who had in the meantime developed structural changes

Financial support for this study was obtained from the Carl Bertel Nathhorsts vetenskapliga och allmännyttiga stiftelser and the Swedish Medical Research Council (Project No K69-?3X-2737-01)

DISCUSSION

The difference between the two groups of men implies that data obtained in this manner cannot be accepted without criticism as a random sample of the population The difference is not readily explained but it may be suspected that the presence of osteophytes as well as symptoms from the lower limbs which cause an arteriography to be made usually arteriosclerosis are both closely linked to the biological age of the individuals and that this link in women is not sufficiently strong to penetrate in these data The difference in the incidence of osteophytes between old men and old women is also unexplained It is however known that osteoarthritis of the knee including obliteration of the joint space and periarticular structural changes is more common in women than in men (Danielsson & Hernborg 1970)

SUMMARY

In 1 179 radiograms of knee joints obtained for reasons other than knee symptoms the presence or absence of periarticular osteophytes was recorded The incidence of osteophytes increased with age and more in women than in men Because of the selection of films the calculated incidence may not without criticism be accepted as equal to that of a random sample of the population

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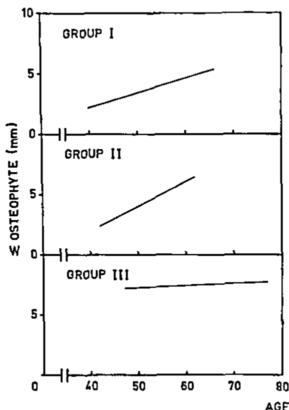


Figure 2 The relationship between age at the time of the initial radiogram and the combined size of knee osteophytes There are significant positive correlations in Groups I and II but not in Group III

Table 1 Age and osteophyte si e at the time of the first radiogram (Av ± SD)

Group	Age	Osteophyte size (mm)
I	53 4 ± 6 8	3 8 ± 2 6
II	52 7 ± 5 0	4 6 ± 3 0
III	6?9 ± 7 6	7 5 ± 3 9

RESULTS

The size of the initially observed osteophytes did not differ significantly between joints which did and joints which did not develop structural changes during the time of observation (Groups II and I)

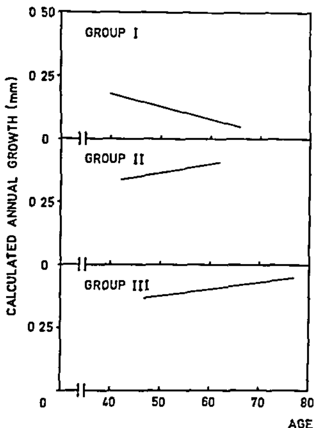


Figure 3 The relationships between age at the time of the initial radiogram and the annual growth of the combined osteophytes (mm/year) The regression lines show a negative tendency for Group I and positive tendencies for Groups II and III

In Group III the osteophytes in the knee joints with structural changes already in the initial radiogram were significantly larger than in the other groups (Table 1) In Groups I and II the size of the osteophytes on the initial radiograms was significantly correlated with age but this was not the case in Group III (Figure 2)

The annual growth of the osteophytes a theoretical variable obtained by dividing the change in size between the first and the second radiograms by the number of years elapsed between the two investigations was compared between the groups in relation to age The calculated growth rate was significantly greater in Groups II and III than in Group I Although as previously demonstrated the size of the osteophytes increased with age the growth rate tended to decrease somewhat with age in Group I In Groups II and III cases with

structural changes as a sign of osteoarthritis there was no such tendency (Figure 3)

Of the 57 cases with previous injury to the anterior cruciate ligament osteophytes were observed in 9

DISCUSSION

As previously demonstrated by Danielsson & Hernborg (1970) the presence of osteophytes does not necessarily indicate that structural changes in the knee joint will follow later on in life The present study also demonstrates that the size of the osteophytes in patients without structural changes offers no guidance to whether such changes will develop The size of the osteophytes increased in the group as such at least up to the age of 70 The growth was more rapid if structural changes that is osteoarthritis developed and the osteophytes continued to grow in osteoarthritic joints

The finding of 9 joints with osteophytes in 59 young individuals who had sustained ligamental injury appears to be more than should be expected in this age group In an experimental study Marshall (1969) was able to produce osteophytes in the knee joints of dogs by dividing the ligaments Therefore age and age related osteoarthritis should not be regarded as the only causes of osteophytes in the knee joints

SUMMARY

Osteophytes in the knee joints are probably most of all related to age and are not necessarily an early sign of osteoarthritis However osteophytes are frequently observed in cases who later on develop osteoarthritis and continue to grow in size in these cases at a faster rate than in cases who do not develop osteoarthritis with structural changes in the joint

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KNEE DISARTICULATION

An Experimental Study

CHR HANSEN LETH & J REIMANN

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In a previous experimental study (Hansen Leth & Reimann 1972) we found in agreement with other investigators (Erikson 1965 Hulth & Olerud 1962) that hypervascularization develops in the stump during the first weeks after a crus amputation The aim of the present study was to investigate the vascular changes occurring in connection with a knee disarticulation and to compare the result with earlier findings in connection with a crus amputation As after an unsuccessful crus amputation the surgeon is often faced with the choice between knee disarticulation and reamputation on crus for the purpose of comparison we have also investigated the state of vascularization after re amputation on crus

MATERIAL

Altogether 26 female rabbits aged approx 3 months were used for the investigation In 10 of the rabbits disarticulation was performed at the right knee At the operation the knee joint was opened with a curved incision with a large anterior flap so the patella was preserved, and gastrocnemei was resected at the insertion on the femoral condyles the inferior patellar ligament was sutured to the cruciate ligaments when the popliteal artery was ligated at knee joint level and then the skin was sutured

As a supplement to the knee disarticulation 6 of the rabbits had a minor osteotomy performed distally on the femur in 2 cases in the form of partial removal of the femoral condyles in 4 cases as partial osteotomy at the distal end of the femur of these 2 were performed in the frontal plane of the epiphysis and 2 in the metaphysis perpendicular to the longitudinal axis

In the remaining 10 rabbits amputation was performed on cru twice with an interval of ½ to 3 weeks one rabbit had however been amputated three times (R 3) The amputations were performed with myoplasty and all under Nembutal anesthesia In 7 of the knee disarticulation cases healing was without reaction in the remaining 3 cases a small dry fistula formation was found (K 7 K 11 and K 15) In the 6 combined operation cases (disarticulation/osteotomy) the stumps

healed without complications In the series of 10 reamputated rabbits dry defect was discovered in the stump in 2 cases (M 6 and H 1)

The rabbits were killed at intervals of 1–4 weeks postoperatively Prior to death tetracycline labelling with Reverin (30 mg/kg body weight) was made twice at an interval of 3 days

In connection with the killing arteriography was performed according to a modification of the Trueta Harrison technique (Trueta & Harrison 1953) Under Nembutal anesthesia the peritoneum was opened and through a catheter in aorta abdominalis saline was perfused at 1 m pressure as simultaneously the animal heparinized beforehand was bled through the vena cava Perfusion was continued with 25 per cent micropaq for approximately 45 min followed by micropaq with 10 per cent formaline for about 15 min Finally the skin was removed from the hind part of the body which was fixed in 10 per cent formaline

All the macroscopic specimens were radiographed using X rays from a Machlett A E G tube (Carl Drenck) The pictures were taken at a distance of 40 cm exposure time 12 min at 12 m Amp and 19 kv Industry film Gevaert Structurix D 7 was used For evaluation of the pictures the classification described by Erikson (1965) was applied taking into consideration the degree of vascular richness the degree of dilation and the presence of tortuous vessels Here it should be mentioned that the arterial conditions in the rabbit differ in more ways from those in man first and foremost in that no arteria profunda femoris exists Instead the arteria genu suprema as well as the arteria saphena are well developed and branch off from the arteria femoralis as two independent branches whereas in man the arteria saphena is a small branch of arteria genu suprema (Brookes 1971)

After radiography the amputation stumps were macroscopically studied Then the distal part of the femur in disarticulation cases and the crus in reamputation cases respectively were sawn off the stumps Corresponding parts from the sides not amputated were removed All the bone specimens were then divided in half by sawing at the frontal plane The posterior parts were used for bone angiography they were decalcified and embedded in methyl metacrylate then cut into slices of 2 5 mm thickness photographed on a spectroscope plate at a distance of 40 cm exposure time 12 min 19 m Amp and 40 kv and evaluated in a stereo microscope SH XX Jena magnification × 10 The anterior parts of the bone specimens were used for investigation of the growth factor on the basis of the tetracycline labelling These specimens were undecalcified fixed in methyl metacrylate then cut out and ground down to a thickness of 50–60 μ They were then studied in a fluorescence microscope where the interval between the two fluorescent lines on the metaphyseal side of the epiphyseal plate was measured The interval which corresponds with the growth in length of the bone between the two tetracycline labellings may vary in the individual specimens owing to the curved sequence of the epiphyseal plate Three measurings have been made on each specimen and 2–3 specimens from each stump were measured

RESULTS

As it appears from Tables 1 and 2 the investigations show that in connection with knee disarticulation hypervascularization in the soft

Table 1 Arteriographical findings in soft tissue

e no	Operation	Time (weeks)	Vascular richness thigh	Vascular width a femoralis	Vascular width a poplitaea	Tortuous vessels
2	Knee disarticulation	1	2	1	1	1
5	–	1	1	1	1	1
6	–	1	1	1	1	1
4	–	1½	1	1	1	1
1	–	2	1	1	1	1
16	–	2	1	1	1	1
7	–	2½	1	—1	—1	2
9	–	3	1	—1	—1	2
11	–	3	1	—1	—1	2
15	–	4	—1	—1	—1	2

Vascular richness 1 Same as at the corresponding level of the intact leg
2 Moderately increased
3 Markedly increased
—1 Less than at the corresponding level of the intact leg

Vascular width 1 Same as at the corresponding level of the intact leg
2 Moderate dilation
3 Marked dilation
—1 Narrower than at corresponding level of the intact leg

Tortuous vessels 1 None 2 Moderate occurrence 3 Abundant occurrence

Time Interval from operation to death of animal.

tissues of the femur was not found except in a single case after re amputation on crus changes were observed distally on the stump where a distinct hypervascularization was found in all cases

As regards the degree of dilation in the arteria femoralis and arteria poplitea a change was not observed until 2½ weeks after knee disarticulation and then in the form of a calibre reduction in comparison with that of the side not amputated We attempted to save the arteria genus suprema which is stated to play a significant part in the blood supply to the stump at the amputation but it was seen only in a few cases and on the whole it was not possible to investigate it After reamputation on the crus moderate vascular dilation was observed during the first two weeks (Figures 1 and 2)

The presence of tortuous vessels which is not a normal occurrence in the musculature is often observed after amputation (Eriksen 1965

Table 3 Arteriographical findings in soft tissue

Case no	Operation	Time (weeks)	Vascular richness thigh	Vascular width a femoralis	Vascular width a poplitaea	Tortuous vessels
Y 14	Knee disart +part osteotomy in epiphyses	2½	1	1	2	3
Y 19	—	2½	1	1	1	2
Y 18	Knee disart +fem condyl resection	2¼	1	1	—1	1
Y 17	—	3	1	—1	1	2
Y 20	Knee disart +part osteotomy in metaphyses	2	1	—1	—1	3
Y 21	—	2	1	—1	—1	1

Explanation as Table 1

Table 4 Angiographic findings and tetracycline labelling in bone

Case no	Operation	Time (weeks)	Angiographic findings in bone (vascular richness)	Growth at the epiphyseal plate
Y 2	Knee disarticulation	1	—1	
Y 5	—	1	—1	—33
Y 6	—	1	—1	—50
Y 4	—	1¼	1	—25
Y 1	—	2	1	
Y 10	—	2	2	
Y 7	—	2¼	2	0
Y 9	—	3	—1	—25
Y 11	—	3	1	+50
Y 15	—	4	3	+100

Time Interval from operation to death of animal

Vascular richness 1 Same as at the intact leg
2 Moderately increased
3 Markedly increased
—1 Decreased

Growth difference Expressed in percentage of the growth of the unoperated side

Table 5 Angiographic findings and tetracycline labelling in bone

Case no	Operation	Time (weeks)	Angiographic findings in the bone (vascular richness)	Growth at the epiphyseal plate
M 8	Reamputation crus	½		+50
H 1	—	1	3	
M 6	—	1	2	+100
H 2	—	1½	2	+50
H 7	—	1½	3	+100
H 5	—	2	3	+100
M 11	—	2	2	+106
H 3	—	2	2	+100
H 8	—	2	3	+200
H 4	—	3	2	+100

Explanation as Table 4

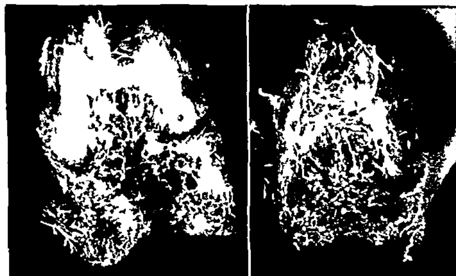


Figure 3 Illustrates bone angiography from case X 4 1½ weeks after knee disarticulation on right side As regards the vascularization no difference between the amputated and unamputated side is found neither in the epiphysis (bottom) nor in the metaphysis (top)

(The amputated side is seen to the left the unamputated to the right)

As regards the presence of tortuous vessels the origin of which is not yet quite elucidated (Hansen Leth & Reimann 1972) they have been found in a number of cases after amputation on the crus (Erikson 1965, Hansen Leth & Reimann 1972, Hulth & Olerud 1962) just as they may be observed in connection with artery occlusion (Allen et al 1946). In the present study tortuous vessels always occurred after a period of about 2½ weeks after disarticulation at the knee and a little earlier after reamputation on the crus. Erikson (1965) proved that the tortuous vessels develop especially in relation to stump pains and necrosis in the stump. Tortuous vessels were found in the three cases of dry fistula formation after disarticulation, whereas not in the two reamputation cases with defect in the stump.

In connection with amputation on the crus (Hansen Leth & Reimann 1972) as well as with reamputation on the crus pronounced hypervascularization in the bone was already observed a few days after surgery; this was not observed in knee disarticulation cases unless an osteotomy was performed at the same time.

Correlation was found between the incidence of hypervascularization and growth stimulation, thus the microangiographic investigations of the epiphysis disclosed hypervascularization in such cases where growth stimulation was observed. This is in agreement with the demonstration by Trueta & Morgan (1960) that growth stimulation depends first and foremost on the vascularization of the epiphysis.

Not only in connection with osteotomy but also in connection with changes in the vascular system may an effect on the growth of bone be seen. Growth acceleration is thus noted in connection with arterial venous shunt formation, increase of the arterial flow or venous stasis. Also immobilization of the extremity without any other intervention may cause changes in the vascular conditions and have an effect on the growth of bone. Thus Hulth & Olerud (1962) found that by immobilization an increased blood flow is observed as is a dilation of the larger vessel and the formation of tortuous vessel. Sundén (1967) reported a growth acceleration in the proximal tibial epiphysis following immobilization obtained by cutting of the Achilles tendon. The hypervascularization in the bone and the growth acceleration which we found 3–4 weeks after knee disarticulation may be a consequence of the lack of use of the extremity operated on.

Contrary to earlier findings in connection with crus amputations the investigations showed that in connection with knee disarticulation no vascular changes occur in the soft tissues. The vascular changes

are conditioned among other things by the development of collaterals branching off from the large branches of arteria femoralis their preservation is attempted in connection with knee disarticulation as well as with crus amputation

The difference between the two operations apart from the cutting of bone is that in connection with an amputation the preserved musculature is cut and sutured

In case of reamputation on the crus a marked increase in vascularization was noted distally in the soft tissue on the stump and more pronounced than in connection with amputation on crus

An osteotomy as that made in the six cases where knee disarticulation was combined with osteotomy at the distal end of the femur had no effect on the vascularization in the soft tissues

From a clinical point of view these circumstances may be of interest as the absence of hypervascularization in the soft tissues after the knee disarticulation may possibly be a contributory cause to the known healing problems often bound at this level (Rogers 1940 Mazet & Hennessy 1966)

SUMMARY

In connection with knee disarticulation performed on growing rabbits the vascular state in soft tissues and bone and the effects of the operation on the growth of bone were investigated The results were compared with an earlier investigation of the vascularization after amputation on the crus and a supplementary investigation of the vascularization conditions in connection with reamputation on the crus Moreover investigations have been made of changes occurring when the knee disarticulation is combined with a minor osteotomy at the distal femur end

After knee disarticulation contrary to earlier findings in crus amputations no hypervascularization occurred in the soft tissues and no dilation of the larger vessels was found but rather a calibre decrease was noted after 2½ weeks By reamputation on the crus a distinct hypervascularization was found distally in the soft tissues of the stump and more pronounced than after amputation on the crus When knee disarticulation was combined with a minor osteotomy no changes occurred in the soft tissues Tortuous vessels were found after disarticulation as well as after reamputation approx 2 weeks post surgery

Angiographic studies of bone have disclosed that no hypervasculari

zation occurs after knee disarticulation unless this operation is combined with an osteotomy and that pronounced hypervascularization in the bone always occurs in reamputation cases just as it was proved in a previous investigation of crus amputation Correlation was found between the occurrence of hypervascularization in bone and growth stimulation

It is concluded that the disclosed absence of hypervascularization after knee disarticulation may influence the healing tendency at this level

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PROCEEDINGS OF THE
SCANDINAVIAN ORTHOPAEDIC SOCIETY
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HELSINKI FINLAND JUNE 1972

THE SPINE

THE DIFFERENTIAL DIAGNOSIS BETWEEN POTT S DISEASE AND TUMOUR OF THE SPINE

Bernhard Paus (Sandvika Norway)

Records and X rays of 50 patients with tumour of the spine verified by histological examination were compared with records and X rays of 50 patients with Pott s disease proven by the finding of Bacillus Koch

In Norway an age under 15 years represents a slight indication for tumour as does history before admission of less than 6 months a history of more than 12 months indicates Pott s disease A hemoglobin below 80 per cent and particularly below 70 per cent heavily indicates tumour as does an ESR of 50 mm or more In uncomplicated cases of Pott s disease ESR is seldom that high. Indeed in clinically doubtful cases without complications or additional disease besides the spinal disease an ESR of 50 mm or more practically always means tumour if unspecific spondylitis can be excluded.

Only one vertebra affected indicates tumour as do changes in vertebral arch or processes Paravertebral soft tissue swelling ("abscess shadow) was seen in 23 of 50 patients with tumour and reduced disc space in 40 This last observation is in contrast to the usual assertion that the disc space stays unchanged in case of tumour

The author concludes that biopsy is indicated for obtaining or verifying the diagnosis as well as for establishing the nature of the possible tumour

FLUOROSIS WITH NEUROLOGICAL COMPLICATIONS

Kjell Harbo (Oslo Norway)

A 56-year-old industrial worker noticed during the last 3 or 4 years progressive muscle wasting loss of strength and pain in his left upper extremity Besides clinical examination showed sensory loss of the left upper extremity and exaggerated tendon reflexes in the lower extremities

X ray of the cervical column revealed extensive changes most pronounced from C_3 to C_6 The vertebral bodies were osteosclerotic irregular in shape with beak like lipping osteophyte formation and calcification of the ligaments

Myelography showed almost complete block at C_6 C_7

The patient had had an ankle arthrodesis 2½ years earlier Roentgenograms taken



Figure 1

during the healing period revealed an unusual degree and form of calcification in the soft tissues

This man had been working in a Norwegian aluminium factory for 16 years and was among the workers most exposed to fluoride compounds liberated through the production process

A decompressive operation of the cervical column a m Cloward was performed The bone structure was unusually hard all through the vertebral body with nearly no signs of normal spongiosa. Biopsies were taken for fluorine analysis The highest value was 2700 p p m bone ash This is much higher than the average values in individuals who have not been exposed to fluoride compounds but at the same time among the lowest values given in the literature for cases with fluorosis

RESULTS OF *OPERATIVE TREATMENT OF HERNIATED INTERVERTEBRAL* DISC

P Salenius & L F Laurent (Helsinki Finland)

During a six year period 1960–1965 886 patients suffering from sciatica were operated on for a protruded disc at the Invalid Foundation Hospital In 1971 a questionnaire was sent to the patients 695 patients answered the questionnaire (78 5 per cent) The material was dealt with by a computer 66 per cent were men *and 34 per cent w men The frequency of sciatica was greatest in the age group* 30–49 years (71 per cent) 122 of the patients had had a previous operation for a

protruded disc A fusion operation was performed in 43 cases 33 patients were later operated for relapse of disc protrusion There were thus 173 patients who had been operated twice (?0 per cent)

Later results indicated that 56 per cent of cases were improved 36 per cent were unchanged and 8 per cent were worse 6? per cent of the cases had nevertheless returned to their previous work 8 per cent had changed their work to a lighter one 7 per cent did not work and 17 per cent were on pension mainly because of advanced age

RESULTS OF LUMBAR INTERVERTEBRAL DISC OPERATION IN CORRELATION WITH PREOPERATIVE AND OPERATIVE FINDINGS

Antti Alho & Erkki Karaharju (Helsinki Finland)

During 1961–1965 a total of 725 sciatica patients were operated on Myelography was performed on 95 per cent of the patients For 84 per cent the finding was considered adequate in the first operated interspace in 30 per cent of the cases another interspace was opened with a positive finding revealed in one half of the patients A prolapsed disc was found significantly more frequently on the left (61 per cent) The level distribution was prolapse between L5 and S1–35 per cent between L4 and L5–6? per cent and between L3 and L4–5 per cent

The straight leg raising test was negative in 7 per cent of the patients with a positive operative finding In the level diagnostics the knee and ankle jerk tests were rather unreliable On the other hand weakness of the extensor hallucis longus muscle and pain radiating to the great toe bore a significant correlation with the prolapsed L4–L5 discs The myelogram was negative in only 5 per cent of the cases with verified prolapsed discs The patients with a negative or questionable operative finding had a longer average history than the patients with an adequate finding The results were best among patients with sciatica of two to six months duration

Twenty one per cent of the patients had distinctive radiating pain two to five months after the operation The most satisfactory results were achieved in patients with an adequate oper tive finding In a follow up study conducted five to ten years later no correlation was found between the prevailing condition and the factors which were important for the immediate postoperative result

ANTERO LATERAL DECOMPRESSION AS A TREATMENT OF FRESH PARAPLEGIA FOLLOWING VERTEBRAL FRACTURE

Erik B Riska (Helsinki Finland)

Six patients with paraplegia following vertebral fracture have been treated with antero lateral decompression operation Three were men and three women age 17 21 28 43 54 and 71 years respectively The level of the spinal lesion was in two cases Th IX and X and in four cases Th XII–L I In four cases the para plegia was complete in two cases incomplete with slight unilateral motor function Two patients had no other traumata one patient a hemipelvic and a radius frac ture one patient a pelvic fracture thoracic injury with flail chest and a fracture of the femoral shaft and calcaneus one patient a rupture of the left lung with flail chest and a pelvic fracture one patient a fracture of the humerus Two



Figure 1 Oxygen myelography of a 43 year old man with paraplegia following a fracture of the first lumbar vertebra Before operation to the left after antero lateral decompression operation to the right

patients were operated on 5 days after the injury one 11 days one 13 days one 38 days and one 6 months after the accident

The exact detection of the compression of the spinal cord is decisive for the decompression procedure A careful examination of the patient should be completed with x ray of the spinal column tomography of the broken vertebra and if necessary with oxygen myelography (Figure 1)

In thoracic spine the operation was done according to the technique of Alexander described by Griffiths Seddon & Roaf In the region of Th XII and L I the incision was made along the XIth rib which was partly resected Psoas muscle was dissected transversely and artery lumbales ligated. The broken vertebra was localized with roentgen television during the operation Compressing bone tissue from the vertebra, loose fragments and compressing discus were removed. Finally the left over thin bony roof between the cavity and the spinal cord was broken down and removed. Interbody fusion was carried out using resected rib fragments as grafts

Two patients made a complete recovery one a good recovery These three patients are back to their former work. One patient walks with crutches without help and the rehabilitation is still going on The follow up time is too short for the two last patients (Table 1)

In a case of traumatic paraplegia one must of course not give too much hope for the patient as a result of operative treatment but if the paraplegia develops gradually within the first hour first day or first week after the trauma a

Table 1

Result of treatment of paraplegia

Patient number	Degree of motor paralysis	Motor function began to return	Result of operation
1	Complete loss	26 days after operation	Complete recovery
2	Incomplete loss	4 days after operation	Complete recovery
3	Incomplete loss	4 days after operation	Good recovery
4	Complete loss	21 days after operation	Moderate recovery
5	Complete loss	21 days after operation	Follow up 30 days
6	Complete loss	–	Follow up 7 days

decompression operation should be undertaken In these cases the compression of the spinal cord is usually from the front and the laminae are in general unbroken If not a posterior fusion might be indicated before mobilizing the patient The results of these six operated cases indicate a more active treat ment of traumatic paraplegia following vertebral fracture instead of the usual conservative treatment

OSTEOSYNTHESIS OF SPONDYLOLYSIS

Klas Buring & Nis Fredensborg (Malmo Sweden)

The method of direct repair of the defect in spondylolisthesis described by J E Buck has been performed on 12 patients—9 men and 3 women The mean age was 32 years (18–49) the postoperative observation period was 1?–19 months The location 9 cases L V 3 cases L IV The indication has been severe irretractable lumbar pain Standing in an upright position had been limited in time and had often hindered the patient in his work. Conservative treatment in these cases had been tried at least one year

Results Nine of our cases are free from pain and have returned to work several having labour work. One girl disabled by lumbar pain became pregnant shortly after the operation however the pregnancy and delivery proceeded uneventfully and she has since resumed her work now free from previous pain Three cases have failed to unite In two of these cases the reason for failure may be due to the fact that the slip was too great as they belonged to Meyerding s group II Here we later carried out an anterior fusion

Conclusion The method of Buck offers a logical alternative to the earlier arsenal of fusions for spondylolisthesis It should however be reserved for cases where the forward displacement of the body does not exceed 4 mm

DISCUSSION

K Harry Sorensen (Odense Denmark)

As pain in cases of spondylolysis and spondylolisthesis is as a rule due to the accompanying disc degeneration fixation of a screw should only be used if the disc is still normal, which is verified by taking a lateral X ray of the disc in question with the patient in a standing posture

In all other cases anterior intercorporal fusion should be performed which will give far safer fixation. At the same time the disc degeneration is treated effectively.

THE TECHNIQUE IN CASE OF ANTERIOR LUMBAR INTERCORPORAL FUSION

K. Harry Sorensen (Odense, Denmark)

The technique is described and illustrated by colour film and a short summary of 84 performed operations is given.

BONE PATHOLOGY

LOCAL RESECTION OF BONE TUMOURS

E. V. S. Koskinen (Helsinki, Finland)

The study describes the local removal of benign, semi-malignant or malignant bone tumours in 171 cases, of which 101 were resections (Figure 1). The follow-up results are presented.

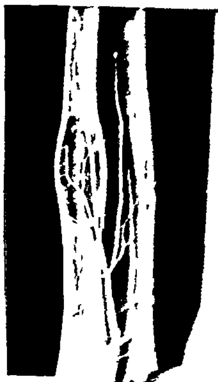
The majority of the tumours were localized close to a joint, which circumstance introduces grave problems in the planning of treatment in view of saving the joint. Part of the tumours recurred, or the tumour was initially malignant or underwent malignant transformation.

The following surgical procedures were applied: (1) removal of tumour and bone grafting, (2) resection of upper end of humerus or ulna or lower end of radius with replacement by fibular graft, (3) resection of diaphysis of humerus with replacement by fibular and tibial graft and metallic implant, (4) resection of tibial condyle with full thickness iliac bone graft, (5) resection of tibial condyle with bone grafting and arthrodesis, (6) resection of lower end of femur

Figure 1. Local removal of bone tumours in 171 cases

Tumour	Resection	Curettage
Chondroma	16	7
Chondroblastoma	2	3
Osteochondroma	21	
Osteoid osteoma	17	2
Hemangioma	1	
Aneurysmal bone cyst	5	5
Fibrous dysplasia	9	23
Fibroma		5
Solitary bone cyst		7
Giant cell tumour	15	18
Chondrosarcoma	7	
Fibrosarcoma	5	
Osteosarcoma	2	
Parosteal sarcoma	1	
Total	101	70

Figure 2 Medullary fibrosarcoma in tibia of woman aged 20 angiograph showing pathological vascularization. Good functional result after segmental resection with massive homograft and assisting autogenic bone replacement and A O plate fixing No recurrence within 2 years



Distraction forces during operation ranging from 20 to 40 kp resulted in corrections of around 50 per cent except in the most severe curve of 120 where it reached only 25 per cent The other curves were not particularly rigid The force declined with time rapidly in the beginning slower after three days After about 12 days the force recorded stabilized at about one third of the maximal force used during operation Recordings also demonstrated the necessity of great care in handling the patients immediately after operation in order to avoid upper laminar fractures In four patients the compression rod on the convex side of the curve was also used In three patients this resulted in an increase in axial force of as much as 5 kp while in one young patient with a less rigid curve of 55 a decrease of the same amount was noted

The axial forces during deep breathing bicycling in bed and similar exercises were relatively low Log rolling caused only a slight increase less when lying on the side of the concavity than on the opposite side

With regard to the axial force the Milwaukee brace compared with no external support in standing exerted a distractive force of 4 to 6 kp in the three patients tested

In the supine position compared with no external support there was a reduction in axial force of 2 to 4 kp when wearing the brace

Evaluation in standing of the different parts of a Milwaukee brace demonstrated the importance of a well fitted pelvic cage of either chin or occiput pads and especially of two side supporting pads

Mechanically these last mentioned results should be valid also for non operated patients with moderate curves of idiopathic origin for whom this brace is commonly used

CORRECTION OF IDIOPATHIC SCOLIOSIS USING MILWAUKEE BRACE AND THE HARRINGTON METHOD

A Langenskiold & O Snellman (Helsinki Finland)

During the period 1969–72 the Orthopaedic Hospital of Invalid Foundation surgically treated 106 cases of idiopathic scoliosis using the Milwaukee brace Harrington instrumentations tibial grafts and ambulation 6 months post operatively *The average correction age in the adolescent scoliosis has been about* 14 years and determination of 71 of these cases between 12–16 years The author presents a two stage operation treatment using a manual correction just before the rod is installed The distraction rod has been used in 94 cases and the compressive rod in 7 cases and both in 2 cases Using this technique the average primary correction was 55 per cent To date the complications include 1 deep infection 1 hook release 4 rods broken (only in cases where the rod was bent at time of surgery) and no pseudarthroses

THE CORRECTION OF IDIOPATHIC SCOLIOSIS USING THE RISSER CAST AND HARRINGTON ROD

C I Nash (England)

During the period of 1969–1971 the University Hospitals of Cleveland Ohio conducted a study of early ambulation following scoliosis spine fusion Forty six

patients with uncomplicated idiopathic adolescent scoliosis were treated with a program of fusion of the major curve using a Harrington distractor rod and iliac graft and ambulation at two weeks in a Risser cast maintained for 5 months

At an average follow up of 17 months there was an average correction of 50 per cent of the average preoperative curve of 59 The immediate postoperative correction averaged 56 compared to 53 standing in the Risser cast at two weeks The only significant complications were two cases of early hook failure causing 5 –10 loss

A MODIFICATION OF THE HARRINGTON HOOK HOLDER

Olai Snellman (Helsinki Finland)

The author presents a modification of the standard Harrington hook holder which grips the hook more firmly between the tips of the holder The surface area of the tip of the holder has been increased in order to stabilise the hook better when rotational forces are applied during insertion of the hook

OPERATIVE TREATMENT OF IDIOPATHIC SCOLIOSIS

J A Sevastikoglou A Hallén & U Lindgren (Umeå Sweden)

This is a preliminary report of 10 patients with idiopathic scoliosis operated on by combined rib resection and spine fusion The cases were selected among a total load of 148 consecutive cases of idiopathic scoliosis largely according to the same indications suggested by Von Lockum (1948) Three were male and 7 were female patients their mean age at operation was 17 5 (range 13–??) years Before surgery the thoracic deformity was evaluated by transversal tomografi of the chest and the patients were stretched in bed according to Cotrell & D Amore (1968) for about 3 weeks During operation 1 to 3 cm from the ribs mainly responsible for the deformity usually 5 to 7 were resected at the most prominent point on the con vexity of scoliosis The medial fragment of the rib was mobilized to the costo transversal joint and the fragments were then approximated and kept together with a suture (mersilene) The resected rib fragments were prepared to some mm thick bone sticks which were transplanted on the previously decorticated concave side of the laminae of the scoliotic curve The patients were stretched in a plaster spicca another 6 weeks post surgery and they were then mobilized with a Milwaukee brace for about 6 months No severe complications were encountered in this material The cosmetic results were very good The degree of correction of the spine deformity was comparable to that reported by Risser & Nordquist (1958) but somewhat inferior to that reported by Goldstein (1969) and Moe & Valuska (1970) where the Harrington instrumentation method was used The effect on the VC and MBC was about the same as reported by Westgate & Moe (1969)

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Department of Thoracic Surgery University Hospital Uppsala Sweden

Distraction forces during operation ranging from 20 to 40 kp resulted in corrections of around 50 per cent except in the most severe curve of 120 where it reached only 25 per cent The other curves were not particularly rigid The force declined with time rapidly in the beginning slower after three days After about 12 days the force recorded stabilized at about one third of the maximal force used during operation Recordings also demonstrated the necessity of great care in handling the patients immediately after operation in order to avoid upper laminar fractures In four patients the compression rod on the convex side of the curve was also used In three patients this resulted in an increase in axial force of as much as 5 kp while in one young patient with a less rigid curve of 55 a decrease of the same amount was noted

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95 measured according to Moe et al (*J Bone Jt Surg* 51 A 293 1969) The brace had an immediate correcting effect on the curve of 23 per cent (9) while the derotation was 16 per cent (4) Those curves that were small and had a small rotation showed the best correction The complications were few 89 per cent of the patients adhered strictly to the treatment program 2 5 per cent demonstrated some changes in the teeth or facial configuration 7 5 per cent had skin problems *Provided the initial contact is well established and the fitting of the brace is made* on an inpatient basis it is possible to treat scoliosis patients in a Milwaukee brace for years without complications and with very few dropouts The brace has an immediate straightening as well as derotating effect on the spine

CONSERVATIVE TREATMENT OF IDIOPATHIC SCOLIOSIS WITH THE MILWAUKEE BRACE

J A Sevastikoglou & P Karlman (Umeå Sweden)

148 patients with idiopathic scoliosis have been seen in the Department of Orthopaedic Surgery Umeå during the last 5 years 57 or 38 4 per cent were considered in need of treatment with a Milwaukee brace 9 were male and 48 female patients The mean age for the onset of the spine deformity was 13 4 for the total material 12 4 for the treated patients Treatment with a Milwaukee brace was introduced at a mean age of 15 4 (range 9–23) years The mean duration of the treatment up to this time is 29 (range 4–56) months The degree of the primary scoliotic curve at the beginning of the treatment as determined by the Ferguson method was $\leqq$ 20 in 4 cases 21 –40 in 33 41 –60 in 18 and $>$ 60 in 2 cases The indications for treatment with a Milwaukee brace and its principles were largely the same as suggested by Blount et al. (*J Bone Jt Surg* 40 A 511 1958) In 13 patients the treatment has been completed 9 of these have been operated 6 patients have interrupted the treatment themselves

The results of the treatment obtained until now in this series of patients are summarized below

	Comparison between radiographic and clinical evaluation of the results	
	Radiographic evaluation	Clinical evaluation
Improved	4 %	25 %
Unaffected	60 %	33 %
Deteriorated	36 %	42 %

These preliminary observations suggest that treatment with the Milwaukee brace

(a) has as the main target the prevention of progress of the scoliotic deformity

(b) often leads to improved body configuration without always improving the scoliotic curve

(c) that it does not seem to solve the problem of the conservative treatment of the patient with idiopathic scoliosis at least in our hands

DENTOFACIAL REACTIONS DURING AND AFTER TREATMENT WITH A MILWAUKEE BRACE

E Dahl (Copenhagen Denmark)

Dentofacial reactions during and after treatment of scoliosis with a Milwaukee brace were demonstrated by X ray cephalometric technique In the evaluated patients tantalum implants were placed in the maxilla and the mandible according to the technique of *Bjork* in order to interpret more accurately the cephalometric findings

It was concluded that dentofacial development should be examined routinely *during treatment with a Milwaukee brace A hard processed acrylic splint worn* during the orthopaedic treatment will prevent or minimize the undesirable changes in the dental occlusion It was recommended that patients be supplied with such an appliance at the beginning of the treatment with a Milwaukee brace The intraoral stabilizing appliance will not completely prevent facial changes It would appear from the reported cases however that a definite tendency for recovery can be expected after brace removal One of the cases showed that reversal of the changes can take place even if the brace is removed in a period without marked growth activity Some morphologic changes in the mandible may remain and radiographic changes in the temporomandibular joint were demonstrated

A STUDY OF THE GROWTH PATTERN IN IDIOPATHIC STRUCTURAL SCOLIOSIS

S Willner (Malmo Sweden)

Most of the etiological factors causing idiopathic structural scoliosis are still unknown However one factor that is generally accepted is growth Growth pattern was studied in a material consisting of 320 girls with idiopathic scoliosis and compared to age matched controls without scoliosis The controls proved to be identical with other age matched Scandinavian measurements of height The loss in height due to the curves was considered and added to the measured standing height *In a cross sectional study it was observed that girls with scoliosis having* late onset (after 10 years of age) were significantly taller than the controls Even in some age groups the uncorrected height exceeded that of the controls In contrast those with early onset did not differ in height from the control group

When the scoliosis was divided into three groups of severities (< 20 20–40 > 40) no differences in height were observed Furthermore a study of height velocity did not reveal any significant differences between girls with and without scoliosis after the age of 10 i e girls with scoliosis had to grow faster earlier in life In conclusion there seems to be a difference in growth pattern between adolescent scoliosis and children without this deformity

SCOLIOTIC DEFORMITIES AND POWER TRANSMISSION OF THE SPINE—A SERIES OF UNIVERSAL JOINTS

F Tidestrom (Linkoping Sweden)

The intervertebral disc may be considered as a universal joint and the whole spine as a series of such This point of view makes it easier to understand not only the construction of the normal vertebra but also of scoliotic deformities

A model of universal joints indicates the locations of the wedged and of the twisted vertebrae It demonstrates too the laws of clinotorsion as a result of combined bendings in the sagittal and the frontal planes In the kyfotic thoracic curve the clinotwist exaggerates the effect of the lateral twist of the yellow ligament This suggests to be the cause of the worst prognoses of the thoracic curves The transversal processes of the thoracic curve are located in a relatively homogenous field of rotation and are of about equal length on each side. In the lumbar curve on the contrary the transversal process of the convex side is in a field of tension both in longitudinal and transversal direction and will be hypertrophic On the concave side the situation is the opposite The concave lumbar transversal process will be extremely small by inactivity

MECHANICAL PROPERTIES OF COLLAGENOUS STRUCTURES IN PATIENTS WITH SCOLIOSIS

Anders Nordwall (Gothenburg Sweden)

Several authors have proposed that an important factor in the etiology of idiopathic scoliosis is a change of metabolism of the body which may cause changes in the biomechanical functions especially of the connective tissue In this study the mechanical properties of the interspinous ligaments and the tendon of the erector spinae muscle were tested for elastic stiffness and breaking strength. The samples were obtained from 35 patients with idiopathic scoliosis and 15 patients with other types of scoliosis undergoing surgical correction according to the Harrington technique

No significant difference in elastic stiffness could be found in interspinous ligaments from different levels of the spine and the distance from the apex of the scoliosis was not of any importance No difference existed between patients from the two scoliosis groups nor was there any significant difference between the two scoliosis groups when strips of the muscle tendon were tested for elastic stiffness and breaking strength

This study excludes mechanical changes in the connective tissue as the cause for idiopathic scoliosis

DISCUSSION

A Nordwall (Gothenburg Sweden)

Variation of biology and method do not permit study of small changes of the mechanical properties with this method We therefore do further studies of the connective tissue from these patients with histological and biochemical analyses and we also study the heat denaturation properties of the collagen These properties are dependent on the biological age of the tissue on a molecular level and are linked with its general mechanical properties

GROWTH DISTURBANCE OF MUSCLE—A POSSIBLE FACTOR IN THE PATHOGENESIS OF SCOLIOSIS EXPERIMENTAL STUDY

S Hakkarainen (Helsinki Finland)

Most methods used to induce experimental scoliosis are either operative or else produce scar tissue which is also known to provoke scoliosis

Table 1

	Results No	Parameter of coliosis
No scoliosis	38	0
Scoliosis straightened	58	1
Constant scoliosis	52	2
Progressive scoliosis	80	3
Indistinct coliosis	25	4
Total	253	

In 1902 Wullstein provoked scoliosis in two dogs by keeping them in a scoliosis position for several months by leather strips On the other hand, it is known that if a muscle is kept immobilized for a long time in a position shorter than that at rest it results in a myostatic contracture (Moll 1886, Davenport & Ranson 1929)

The present material consists of experiments made on 253 rabbits of 2–5 weeks. They were immobilized by a plaster cast in a scoliotic position for 2–5 weeks, the plaster being changed once a week The development of scoliosis was recorded radiologically The results are presented in Table 1 Scoliosis developed in 183 rabbits or 72 per cent Scoliosis is more apt to develop the younger the animal is at the time of plastering and the longer the time spent in plaster

The lengths of the intercostal muscles on the concave side were measured on preparations of part of the rabbits and they were found to have shortened

Seventy scoliotic rabbits were operated on by cutting the costotransversal *ligaments* and by removing the dorsal part of the intercostal muscles in 2–4 intercostal spaces on the concave side Fat tissue was transplanted in the operated intercostal spaces to prevent cicatrization Table 2 shows the distribution of the operated cases into different classifications of scoliosis and the effect of the operation

Table 2

		Parameter of scoliosis 0	1	2	3	4	Frequenc	Per cent
		No of experiments						
Parameter of operation	0	*No of experiments*		4	12			23
	1							11
	2							30
	3							20
	4							16
Frequency					7			—
Per								—

(Parameter of operation 0 = no effect 1 = slight effect 2 = cessation in progress of scoliosis 3 = regression 4 = indistinct effect) The result of the operation was positive in 61 per cent

It is evident that in these experiments there is a muscle contracture on the concave side and it seems natural that the same phenomenon would also be found in man in idiopathic scoliosis

SPINAL FUSION AND THE CORRECTION OF THE EXPERIMENTAL SCOLIOSIS IN GROWING RABBITS WITH FREE PERIOSTEAL GRAFTS

V Ritsila S Alhopuro O Snellman & S Hakkarainen (Helsinki Finland)

Experimental attempts to produce solid fusion of the growing spine have generally been unsuccessful. Therefore spine fusion experiments have failed to throw much light on the clinical problems of early spine fusion In rabbits spinal fusion has been attempted but not achieved Continued growth in length of the spines of young animals routinely occurs after spine arthrodesis in which gross pseudarthroses have developed at each interspace

In an earlier article by Veijo Ritsila and Sakari Alhopuro a bony fusion was achieved in different regions of the thoracic and lumbar spine with free periosteal transplants In unilateral fusions this caused a progressive scoliosis

In the present study this new model of spinal growth disturbance is used in attempts to correct experimental scoliosis provoked with other methods When a progressive scoliosis has developed free periosteal graft from the tibia of the same animal is transplanted to the convex side of the spine between the spinous and articular processes overlying the vertebral facets

With this method we could achieve spinal fusion and stop the progression of experimental scoliosis It is possible that in early fusion gradual straightening of slight or moderate scoliosis will take place

DISCUSSION

J A Sevastikoglou (Umeå Sweden)

From the scoliosis symposium of this meeting it seems justified to draw the following conclusions as to the trends in the care of scoliotic patients in Scandinavia the concentration of which in some few centers is under development The use of the Milwaukee brace as the method of choice for the conservative treatment of the condition is spreading Harrington s method is on the other hand used in several places but other methods have also been tried for the operative treatment of scoliosis The active attitude is thus adopted increasingly but the problem of scoliosis is yet not solved There is therefore, no place for dogmatism for our acting Further research regarding the etiology and pathophysiology of scoliosis and the development of new principles and methods of treatment are necessary and in this respect the activities of the institution headed by Dr Langenskiold are the only example to follow

THE HIP

VARUS ROTATION OSTEOTOMY IN THE TREATMENT OF PERTHES DISEASF A PRELIMINARY REPORT

L. E Laurent (Helsinki Finland)

In patients with Perthes disease in which X rays indicate a head at risk" (Catterall 1971) conservative treatment gives bad results The results of treatment



Figure 1

with a Thomas splint at the Invalid Foundation Hospital were good in only about 50 per cent of the 165 cases followed up (Edgren 1965) Varus rotation osteotomy with centering of the head into the acetabulum performed in good time seems to improve the results (Axer 1965 Somerville 1971) In my opinion subluxation of the head is an absolute indication for osteotomy The preliminary results of twenty hips with an observation time of one to two years after operation indicate that good results can be achieved if the osteotomy is performed before irreparable changes occurred However an osteotomy performed too early seems to be unable to prevent progression of the disease with recurrence of the subluxation Even in cases where irreversible changes have already occurred it is worth correcting the subluxation with an osteotomy because better congruence between the joint surfaces can still be achieved In cases where the damage of the capital epiphysis has led to premature closure of the growth plate with a progressive coxa vara deformity an epiphyseodesis of the greater trochanter should be performed (Langenskiöld & Salenius 1967)

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DEROTATION VARIZATION OSTEOTOMY IN THE TREATMENT OF PERTHES DISEASE

S Haraldsson (Reykjavik, Iceland)

At the Orthopaedic Clinic Harnösand Sweden 27 subtrochanteric derotation varization osteotomies of the femur in 26 patients were performed between Sept 1966 and Sept 1971 for Perthes disease Osteosynthesis with metal plate After 8 weeks in plaster cast full mobilisation with return to normal unrestricted life Mean age 5 1 years in 20 boys and 6 girls At the operation 14 hips showed the initial stage of Waldenstrom 13 showed the fragmentation stage

Review of 26 hips Mean observation time 2 6 years All patients were free from pain and lived a normal life without physical restraint The osteochondrotic process at the review was healed in the first 10 hips and in hips nos 12 and 21 Thus of these 12 hips in the growing period of Waldenstrom (healed but not full grown) 9 had been in the initial stage and 3 in the fragmentation stage when operated upon

Roentgenographic criteria at review (Table 1) (1) epiphyseal quotient of Sjöwall

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Figure 1 A boy 6½ years old at diagnosis Treated with a Thomas splint 26 months preoperatively The preoperative radiograph shows significant subluxation and fragmentation The preliminary result 12 months later is good

Table 1 Derotation varisation osteotomy in treatment of Perthes' disease
12 cases healed at review

Case no.[1]	Age at operation	Sex	Stage at operation (Waldenström)	Interval onset → 1st healed radiograph	Total involvement of nucleus	Duration of observation (op → review)	Epiphysial quotient %	Anatomical result from radiogr.: Method of Mose	Measurements at review: CE angle	Classification
1	1 yr 8 mo	female	initial	3 yr 3 mo	yes	4 yr 10 mo	97	20/20[2]	30/3[illegible][3]	good
2	[illegible] yr 7 mo	male	initial	4 yr 3 mo		4 yr [illegible] mo	93	24/26	15/2[illegible]	fair
3	7 yr 6 mo	female	initial	3 yr		4 yr 7 mo	[illegible]5	26/28	3[illegible]/[illegible]0	fair
4	3 yr 8 mo	male	fragmentation	4 yr 6 mo	yes	4 yr 6 mo	80	22/2[illegible]	25/30	good
5	5 yr	female	initial	3 yr 2 mo	yes	4 yr	93	20/20	25/25	good
6	4 yr [illegible] mo	male	initial	3 yr 10 mo	yes	3 yr 7 mo	90	20/20	25/2[illegible]	good
7	2 yr 3 mo	male	initial	1 yr 8 mo	yes	3 yr 5 mo	92	16/16	25/25	good
8	7 yr 1 mo	male	initial	2 yr 7 mo	yes	3 yr 4 mo	92	20/20	30/30	good
9	[illegible] yr 4 mo	male	initial	2 yr 5 mo	yes	3 yr 1 mo	72	20/20	20/25	fair
10	4 yr 8 mo	female	initial	1 yr 9 mo	yes	3 yr 1 mo	93	16/16	25/30	good
12	[illegible] yr	male	fragmentation	3 yr 1 mo		2 yr 8 mo	84	16/16	20/25	good
21	3 yr 3 mo	female	fragmentation	1 yr 7 mo	yes	1 yr 9 mo	78	12/12	25/25	good

[1] Of 27 hips operated upon 12 showed growing period of Waldenstrom at review (healed but not full grown)
[2] The two figures are frontal view/lateral view
[3] The operated hip is given first

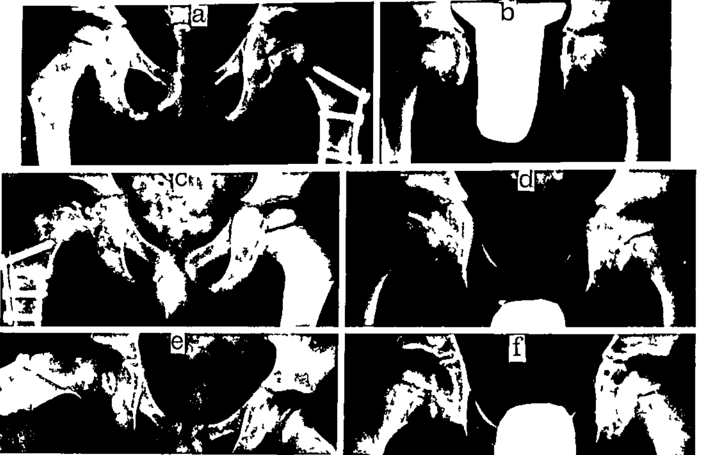


Figure 1 Results after osteotomy A Hip 1 Fragmentation stage B Hip 1 Healed I Q 87 % C Hip 4 Healing period D Hip 4 Healed F Q 80 % E Hip 6 Fragmentation stage F Hip 6 Healed E Q 90 %

(assessment of flattening) (2) concentric circle template method of Mose (spherical shape) (3) C-E angle of Wiberg (spatial relation head/acetabulum)

According to these criteria the anatomical results were classified as good in 9 and fair in 3 of the 12 hips healed at review (Table 1)

Compared with the results after prolonged conservative treatment these preliminary results after a therapeutic measure lasting 2-3 months are considered sufficiently favourable for continuation on the described therapeutic line

HIGH FEMORAL OSTEOTOMY AS TREATMENT FOR OSTEOARTHRITIS OF THE HIP JOINT

H Appel & S Friberg (Umeå Sweden)

During the period of 1959-69 161 high femur osteotomies were made in 147 patients at the Department of Orthopaedic Surgery in Umeå Sweden Three different methods of osteotomy were used These three methods were performed during different periods of time and no selection of cases to a specific method were made.

Method 1 *Varisation or valgisation osteotomies with internal fixation*

Method 2 Transverse osteotomy *without dislocation* after internal fixation with nail and plate (Nissen)

Method 3 Subtrochanter c Z or L osteotomy *without dislocation* and internal fixation with screws

Results of follow up examination

	No of hips	Obs time	Total relief of pain: pain at rest	Total relief of pain: pain on motion	Patients assessment improved
Method 1	36	6 6	66 %	30 %	69 %
Method 2	27	9 4	62 %	22 %	70 %
Method 3	49	6 4	65 %	24 %	78 %

The results clearly show that the high femoral osteotomy has a good and lasting effect on pain at rest and that the long term effect on weight bearing pain is less prominent No statistical differences exist between the three different operative methods

These results cannot be explained by the purely mechanical" theories of effect of an osteotomy (Pauwels Blount) On the contrary they support the theories of an effect of the osteotomy on the vascular supply to or drainage from caput femoris (*Helal Nissen Phillip Arnoldi et al*)

DISCUSSION

Hans N Gregersen (Alborg Denmark)

Question to Helge Appel & Sven Friberg

From your figures we saw no difference in the results of treatment whatever type of osteotomy you used.

Do you think you would obtain the same results if you used a simple myelotomy?

S Friberg (Umeå Sweden)

About 10 myelotomies were performed in Umeå during the period of 1959–61 The immediate results were good but rapid reappearance of the preoperative symptoms in one to two years were found. However in theory a myelotomy should be just as good as an osteotomy and further investigation of the effect of a myelotomy on the patients symptoms and on the intramedullary hypertension are now undertaken in Umeå

EXPERIENCES WITH A HUNDRED SUBTROCHANTERIC VALGUS OSTEOTOMIES

Knud Jørring & Rasmus Movin (Copenhagen, Denmark)

During the period 1961–1971 10? patients had subtrochanteric valgus osteotomy performed at the Surgical Department A Frederiksberg Hospital Copenhagen

The operation was carried out by a method earlier published by Movin in the Danish Society of Surgeons

The procedure was performed on 79 patients with sequelae after fracture of the neck of the femur and on 23 patients with osteoarthritis of the hip

Eighty three of the patients underwent a postoperative clinical and radiological examination with an observation time of at least one year

All osteotomies healed In one case re-operation was necessary 7 months after the primary operation to achieve healing

The procedure had a satisfactory effect on the often disabling pains of the patients but the mobility of the joint and the walking capacity was not influenced accordingly

The incidence of deep infection in this series was high (6 per cent) In all 6 patients it caused removal of the osteosynthetic material The osteotomies healed but the results had considerably deteriorated.

In consequence of this complication our operating room conditions have been revised

THE FIRST HUNDRED INTERTROCHANTERIC DISPLACEMENT OSTEOTOMIES WITH THE NEW COMPRESSION PLATE

P Salenius (Helsinki Finland)

Despite recent developments in the treatment of painful osteoarthritis of the hip joint particularly by means of artificial joints intertrochanteric displacement osteotomy still has its place especially in the treatment of young patients Stable internal fixation is an absolute necessity for complete and rapid recovery after intertrochanteric displacement osteotomy

Three years ago at a meeting of the Finnish Surgical Association I introduced a compression plate which I had used for several years and which I had published in the *Journal of Bone and Joint Surgery* in 1970 The plate is of stainless steel in one size only and is manufactured by Zimmer in England.

The fitting of the plate is usually very simple The hook at its upper end is fitted over the greater trochanter and pulled downwards with a forceps The plate is fixed with two AO screws to the proximal fragment of the osteotomy After fixation of the proximal fragment an AO type compression device is fitted to the distal end of the plate and the fragments are pressed together It is n w important

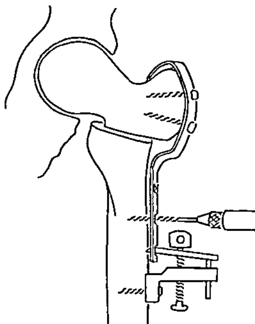


Figure 1 The fragments of the osteotomy are compressed together with an AO compression device The hook of the plate must rest on the trochanter A very good compression and stable fixation is usually obtained



Figure 2 About 40% of the osteotomies consolidated in 6 weeks as did this case and the majority in less than three months Only one non union occurred in the series of the first 105 osteotomies (0.95%)

that the hook at the upper end is immediately over the trochanter so that the compression force rests on the trochanter and not on the two upper screws (Figure 1) The fragments are then compressed together and the distal fragment is fixed to the plate with AO-screws.

Until now about 300 osteotomies have been performed with this plate beginning in 1968 The first 105 osteotomies are analysed here There was only one non union, a patient who refused weight bearing and who had used cortisone for her rheumatoid arthritis. One-third of the patients left the hospital in less than two weeks. Full weight bearing was started 6–8 weeks after the operation At this stage about 40 per cent of osteotomies were considered consolidated (Figure 2) The majority about 65 per cent were considered consolidated in less than three months.

On the basis of this follow up examination of the first hundred intertrochanteric osteotomies, the new compression plate may be recommended for internal fixation of the intertrochanteric displacement osteotomy of the femur

LOCAL AMLOID DEPOSITS IN THE FIBROUS CAPSULE IN CASES OF OSTEO ARTHRITIS OF THE HIP

K Harry Sorensen & H E Christensen (Odense Denmark)

At the Department of Orthopaedic Surgery and the Institute of Pathology Odense Hospital, Denmark 60 biopsies from the hip joint capsule removed after total hip replacement (Charnley) were examined from November 1970 to May 1972

In 19 biopsies amyloid was histologically demonstrated in the fibrous capsule after staining with alcaline Congo red and demonstration of green dicroism with polarized light In cases of primary idiopathic osteoarthritis amyloid was found 3 times more frequently in men than in women By rectal biopsy examination of the bone marrow serological tests for rheumatoid arthritis and serum protein examination and clinical examination for rheumatoid arthritis and myelomatosis were excluded for which reason it was a question of quite local occurrence of amyloid

There was no correlation between age duration or the degree of severity of the osteoarthritis (Merle d Aubigne s scale) and the occurrence of amyloid or the quantity of this and there was no correlation between amyloid and possible simultaneous occurrence of hyalinization or inflammation or previous injection of hydrocortisone

DISLOCATION OR SUBLUXATION OF THE HIP FOLLOWING IMMOBILIZATION OF THE KNEE IN EXTENSION IN YOUNG RABBITS

J F Michelsson & A Langenskiöld (Helsinki Finland)

The effect of immobilization of a leg on the hip in growing rabbits was investigated In 85 one to eight week old rabbits one of the hind limbs were immobilized with the knee in extension and the hip free and movable In almost all of the rabbits a dislocation or subluxation gradually developed The development of the changes in the hip was dependent on the age of the animal and the duration of the immobilization The younger the animal and the longer the duration of the immobilization the more marked were the changes in the hip After a short period of immobilization a partial or complete regression of the changes in the

hip developed The extension of the knee led to increased tension in the hamstring muscles If these muscles were cut and an immediate subsequent immobiliza tion was performed no or only slight changes in the hip of the immobilized limb developed The present investigation shows that in young rabbits simple immobilization of the knee in an extended position leads to changes resembling congenital dislocation of the hip in man These facts contribute to clarify the unclear pathogenesis of human congenital dislocation of the hip

INTRAVITAL OXYTETRACYCLINE LABELLING OF THE HUMAN FEMORAL HEAD

P Rokkanen & P Slatis (Vasa Finland)

The viability of the femoral head after subcapital fracture of the neck has previously been evaluated by arteriography venography bone seeking isotopes and various intravital staining techniques None of these has been routinely used and the condition of the femoral head is still usually evaluated from plain radiographs

Intravital labelling of the femoral head by parenteral administration of oxy *tetracycline prior to surgery was done in 69 patients with subcapital fractures* of the femoral neck The femoral head and an appropriate part of the femoral neck was replaced in all cases by a metallic endoprothesis

In fresh fractures fluorescence microscopy of the removed and methyl metacry late embedded specimens revealed an almost complete lack of oxytetracycline up take indicating severely impaired nutrition of the cancellous bone Two exceptions from this were noted uniform fluorescence obviously due to transchondral up take from the synovial fluid was observed subchondrally in a marrow zone beneath the hyaline cartilage Secondly fluorescence was observed in inveterate cases in areas of recent bone repair

It is concluded that the viability of the femoral head after subcapital dislocated fracture of the neck is uniformly and seriously impaired

INTRACAPSULAR FRACTURES OF THE FEMORAL NECK TREATED WITH CHRISTIANSEN S HIP PROSTHESIS WITH TRUNNION BEARING

J Aamold & U Slungaard (Oslo Norway)

In the Orthopaedic Department Aker Hospital Oslo 61 patients with dislocated fractures of the femoral neck were treated with primary replacement arthroplasty during the period April 1969 to January 1972 with insertion of the Tor Christiansen trunnion bearing endoprosthesis Most of the patients were more than 70 years of age The operation was done through a posterior approach and early full weight bearing was allowed There were no technical complications and no deep infec tions 5 patients died within 2 months after the operation and 6 other patients had died before the follow up The average length of follow up was 11 2 months All 50 living patients were examined According to Love s criteria 30 patients (60 per cent) were classified as excellent 11 patients (22 per cent) as good and 9 patients (18 per cent) as fair Some of the patients classified as "fair were put in this group because of other factors than the results of the hip operation e g hemiplegia.

We find the results encouraging and will continue to use the Christiansen hip prosthesis in cases where we find primary replacement arthroplasty indicated

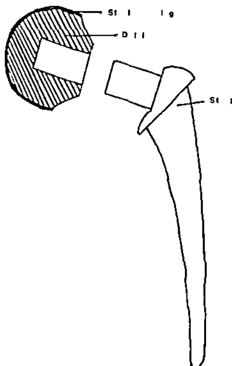


Figure 1

TROCHANTERIC FRACTURES OF THE FEMUR TREATED WITH A KUNTSCHER NAIL

E B Riska & M Lyytikainen (Helsinki Finland)

Twenty three patients with pertrochanteric fractures were treated with a Küntscher nail inserted through the medial femoral condyle after reduction of the fracture on the operating table under general anesthesia Three were male and 20 female with an average age of 77 years Four of the patients had a comminuted pertrochanteric fracture

Mobilization of the patient was started on the day after the operation and full weight bearing was allowed directly 18 patients left the hospital within four weeks 4 of them as dead 5 of the patients were hospitalized between 5 and 8 weeks

Good union of the fracture was verified in 12 cases within 2 months in 3 cases within 3 months and in 4 cases within 4 months after the operation Good result of treatment was achieved in 19 cases (Table 1 Figure 1) Four patients died within 2 weeks two of pulmonary thromboembolism two of heart infarction No infections were recognized

The trochanteric Kuntscher nail gives a good fixation of a pertrochanteric fracture but the reduction of the fracture before nailing must be good and roentgen television is imperative for the procedure Early mobilization of the patient is possible and full weight bearing on the operated extremity is directly allowed The results of treatment are good Our small material confirms the good results



Figure 1 A woman of 70 years with a pertrochanteric fracture of the femur treated with a Küntscher nail inserted through the medial femoral condyle To the left before operation to the right two years after the operation Good union of the fracture

in 88 patients presented by Küntscher in 1969 and encourages us to continue with this method in the treatment of stable pertrochanteric fractures but some instable or comminuted pertrochanteric fractures can also be treated with this method

Table 1 Results and complications of the treatment of 23 patients

Result and complication	Number of patients
Union of the fracture within	
2 *months*	12
3 months	3
4 months	4
Good result of the treatment	19
Primary mortality	4
Infections	0
Tromboembolic disease	0 (2)

DISCUSSION

L Hult (Stockholm Sweden)

I would like to mention briefly a similar method for trochanteric fractures where intramedullary inserted elastic condyl nails described by Josef Ender in Austria are used The nails are 35–49 cm long and 4½ mm thick and are bent in a manner to be suitable for the purpose After closed reduction of the fracture the first nail is inserted intramedullarly from the medial femorial condyle and under X ray television brought up through the fracture area up into the femoral head *To get good stability another 1–3 nails are inserted It is* important that the nail length be exact and it is very easy to change the first nail if it is too long or too short after the second nail has been inserted The fixation is very stable and allows early weight bearing We have used this method on more than 100 cases during the last year in Sodersjukhuset in Stockholm and are very satisfied because the intervention is easy and quick gives very little bleeding and is not stressing for the patient The healing seems to be quicker and safer than with the ordinary nail and plate I also feel that these nails are easier to use than the Küntschner nail.

SUBCAPITAL FRACTURES OF THE FEMUR TREATED WITH TWO THIN SMITH PETERSEN NAILS

E B Riska & M Lygtikainen (Helsinki Finland)

Twenty four patients with subcapital fractures of the femur were treated with two thin Smith Petersen nails 6 were male and 18 female with an average age of 42 (range 18 to 66) and 68 (range 40 to 89) years respectively 8 patients had a stable Pauwels I type fracture 8 Pauwels II type fracture and 8 an instable Pauwels III type fracture of the femur

Sixteen patients were hospitalized less than two weeks 8 between 3 and 4 weeks and one patient 9 weeks 10 patients were allowed full weight bearing of the operated limb within one month then within 2 months and 4 after 5 months postoperatively Because of short follow up times only primary results could be presented but in 14 cases the follow up period was over 12 months

In 23 cases good union of the fracture was recorded (Table 1 Figure 1) Thrombo phlebitis was noticed in one case and postoperative infection in one case who



Figure 1 A woman of 70 years with a pertrochanteric fracture of the femur treated with a Kuntscher nail inserted through the medial femoral condyle To the left before operation to the right two years after the operation Good union of the fracture

in 88 patients presented by Kuntscher in 1969 and encourages us to continue with this method in the treatment of stable pertrochanteric fractures but some instable or comminuted pertrochanteric fractures can also be treated with this method.

Table 1 Primary results and complications of the treatment of 24 patients with two thin Smith Petersen nails

Result and complication	Number of cases
Good union of the fracture	23
Died within five months	0
Thromboembolic disease	1
Infection	1
Pseudarthrosis	1

developed a pseudarthrosis of the femoral neck In all other cases the movement on the hip joint was normal at the time of the last follow up examination and the patients walked without limp

This method with two thin Smith Petersen nails was presented because it is simple and easy to perform for every orthopaedic surgeon Roentgen television is beneficial for the nailing procedure A good reduction of the fracture before nailing is imperative The method is suitable especially for younger cases but also for older patients with subcapital fractures of the femur which are not treated with an endoprosthesis

THE PELVIS

ARTERIAL INJURY IN FRACTURE OF THE PELVIS

V M Huittinen & P Slatis (Helsinki Finland)

Following Miller s suggestion (1963) several reports were presented on ligation of the hypogastric arteries to control severe haemorrhage within the fractured pelvis There is no firm evidence however about the frequency or site of arterial injury associated with pelvic fractures and indications for surgical intervention are in dispute

In 27 medico legal autopsies on accident victims with pelvic fractures selective angiograms of the hypogastric arteries were done with a Micropaque gelatin solution In 23 of these injury to the arteries and extravasation of the radiopaque material could be demonstrated The arterial injury was bilateral in 17 cases unilateral in 6 cases and comprised three or more simultaneous lesions in 14 cases The most frequent sites of leakage were in the immediate vicinity of the sacro iliac joint and the sciatic notch (17 cases) and in the area of the uro genital diaphragm (6 cases) The major part of the haemorrhage occurred retro peritoneally but in severe injuries the haematoma extended along the piriformis muscle through the sciatic foramen into the gluteal region

The results of the present series show that ligation of the hypogastric artery should always be bilateral Whether this procedure will arrest further bleeding is doubtful in cases with either multiple arterial injuries or extensive damage to the bone and adjacent structures Reduction with firm apposition of the profusely oozing bone fragments against each other is obviously an important step in attempts to control bleeding Routine procedures in these situations comprise adequate blood volume replacement early reduction of the pelvic fracture



Figure 1 A woman of 2? years with an instable pelvic fracture treated operatively with pin fixation The fracture and luxation of the femoral head to the left Situation after pin fixation in the middle and 19 months after the operation to the right

and support of the girdle in a pelvic sling If the bleeding still continues bilateral ligation of the hypogastric arteries may be considered.

OPERATIVELY TREATED PELVIC FRACTURES IN 26 PATIENTS WITH MULTIPLE INJURIES

E B Riska & M Lyytikainen (Helsinki Finland)

Instable pelvic fractures of 26 patients with multiple injuries were treated operatively between 1969 and 1971 19 patients were male and 7 female with an average age of 38 years 24 had a traffic accident 2 fell from height 12 patients had a comminuted fracture of the acetabulum 12 comminuted fracture of the pelvis one an instable hemipelvic fracture and one a rupture of symphysis and the sacro iliac joint In 13 patients a cerebral concussion was recorded as an associated injury 4 patients had in addition to the pelvic fracture hemopneumothorax 11 patients rib or sternal fractures 4 flail chest 7 patients intra abdominal injuries in need of urgent surgical treatment 13 long bones and 9 short were broken Rupture of ligaments in the knee joint was noted in 4 patients and a rupture of a big artery in 2 patients In addition 20 patients had multiple lacerations and wounds 2 ocular injury and 5 got a thromboembolic disease Because of multiple injuries most of the patients were treated during the first days in an intensive care unit

In 21 patients the pelvic fracture was osteosynthetized with Vitallium or AO screws in three with AO plates and screws in one case with Supramid and in one case with Johansson pins (Figure 1) 13 patients were mobilized within 4 weeks but 11 only within 7 weeks

All 26 patients were followed up 17 of them over 1¼ years after the accident 19 of 26 patients were back to their former work (Table 1) 14 patients had almost normal range of movement of their hip joints No deaths were recorded At the follow up examination 7 patients were unable to work but 2 of them were over 65 years of age 10 patients had pains in their hip joint and limited range of movement In 7 cases osteoarthritis of the hip joint was recorded in need of additional treatment later

Considering the severe multiple injuries the result of treatment especially the operative treatment of the pelvic fracture was good The rigid osteosynthesis of

Table 1 Results and Complications of the Treatment of 26 Patients with Multiple Injuries and Operatively Treated Pelvic Fractures

Result and complication	Number of patients
Back to work	19
Almost normal hip joint	14
Mortality	0
Still unable to work	7
Pain in the hip joint and reduced mobility	10
Secondary osteoarthritis	7

the instable pelvic fracture allows early mobilization of the patient which is imperative for the good result of treatment of other injuries e g fractures of long bones and chest injuries The disability was slight in 19 patients who were back to work but after ten years the situation might be different

SHOULDER SYMPOSIUM

EXPERIENCES IN OPERATIVE TREATMENT OF PERFORATING RUPTURES OF THE ROTATOR CUFF

G Bakalim & M Pasila (Helsinki Finland)

The series consists of 55 patients with perforating rupture of the rotator cuff operatively treated at the Department of Orthopaedics and Traumatology Helsinki University Central Hospital in 1960–1970 The majority (45/55) were 40–59 years old Three patients were under 40 7 over 59 The indication for operation was painful weakness of the shoulder joint and nocturnal pain In general ruptures *of the rotator cuff were conservatively treated Of 193 patients treated at the* Department of Physiotherapy in 1960–1965 only 24 were operated upon Operative

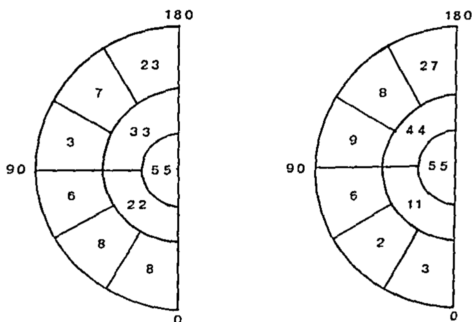


Figure 1

repair was chiefly attempted in patients in heavy labour whose response to physiotherapy was unsatisfactory It was a condition that passive abduction should be almost complete preoperatively

Over half the patients (30/55) were operated on during the first 3 months 43/55 during the first 6 months Only 12/55 were operated on later In 23/55 cases the rupture was large (over 3 cm) Acromion resection varying in extent was done alone 16 times in conjunction with repair of the rotator cuff 20 times Acromion resection alone was seldom (6/40) performed sooner than half a year after injury more often (10/15) later Repair of the rotator cuff was the only procedure in 19 cases

Postoperative improvement of active abduction in the total series is shown in Figure 1 Abduction was impaired in some cases Impairment was infrequent (1/19) in cases treated by repair of the rotator cuff alone more frequent (8/36) when acromion resection was performed

As regards the end results particular attention was paid to return to heavy labour 23/44 patients returned to heavy labour (Table 1) All of 4 patients operated on within a month, 13/32 operated on within 6 months and 6/8 operated on later returned to heavy labour

Table 1 Unfitn ss for worl and return to heavy work

	Duration of unfitness for work			Total
	3 months	3-6	6-9	
Returned	11	10	2	23
Not returned				21
Total				44

OPERATIVE OR CONSERVATIVE TREATMENT OF TOTAL DISLOCATION OF THE ACROMIOCLAVICULAR JOINT

G Bal alim & F Wilppula (Helsinki Finland)

A follow up investigation was performed on 41 patients with total dislocation of the acromioclavicular joint treated at the Department of Orthopaedics and Traumatology Helsinki University Central Hospital in 1963–1969 The average follow up time was 4 3 years Nineteen patients were surgically treated 22 conservatively The procedures performed were repair of the coracoclavicular ligament and fixation of the acromioclavicular joint by a Kirschner wire In the conservatively treated cases a dressing was applied to aid reduction of the acromioclavicular joint

The shoulder was immobilized for an average of 5 weeks postoperatively for 3 weeks in the conservatively treated cases The operatively treated patients were unfit for work for an average of 12 weeks the conservatively treated patients for 5 weeks

The end results were evaluated on the basis of the patient s subjective symptoms (pain on effort change of occupation) and objective findings at follow up examination (instability of the acromioclavicular joint and related tenderness range of motion of the shoulder joint strength on abduction radiological appearance) A

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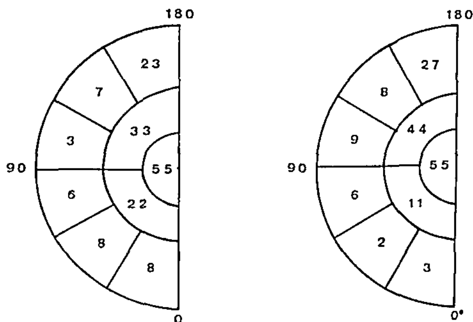


Figure 1

4 The cerclage wire should not be removed routinely
5 No case of definite posttraumatic arthrosis was recorded
6 After trauma the joint can be remodelled from a vertical type to a more horizontal one

DISCUSSION

Knud Jansen (Copenhagen Denmark)

A recent follow up study performed by Dr Rosenorn on cases treated by primary operative treatment did not reveal similar excellent results as reported here

In conservative management the problem is to offer effective and tolerable bandages

In late cases I have had good results with the Dewar operation and with acromio clavicular fascial cerclage

Recently the plasty applying the coracoacromial ligament seems to offer promising results

The angle of the joint is most interesting in particular whether the sloping joint is a primary finding or a sequel to dislocation

DISCUSSION

H G Fdeland (Gothenburg Sweden)

In me instances of dislocations of the acromioclavi ular joint ligamentous structures carrying the nerves to the joint are ruptured above all branches of the uprascapular and supraclavicular nerves This probably explains why pain most often is not the dominant trouble with persistent joint dislocation

A Freskar (Gothenburg Sweden)

I recommend arthrotomy because in several patients where this was not done the j int was still dislocated at the end of the operation Arthrotomy ought to prevent this

X ray examination under stress in order to diagnose a dislocation in the acromio clavicular joint is of limited value If one is to use the method it must be a passive stretching in both arms The patient should not actively carry weight

FRACTURES OF THE SCAPULA WITH GREAT COMMUNITION AND DISPLACEMENT

A Dambolt & D Zdravkovic (Odense Denmark)

660 patients with fractures of the scapula were treated conservatively Most of the patients had multiple lesions and had received severe injury 40 patients had fracture at the upper lateral angle with serious dislocation and communition These 40 p tients were e pecially examined

The results after conservative treatment were good All the fractures were healed No patients had limitation of strength and the mobility in the shoulder wa nl limited in few ca es Deformity was still seen in x ray but onl one had clinical deformit

FRACTURA SCAPULAE

H K Gregersen (Alborg Denmark)

During a period of 11 years 63 patients with fracture of the scapula were treated as inpatients at the surgical departments at Aalborg Sygehus Syd, Denmark There were 50 males and 13 females The frequency of the fractures was evenly distributed in age groups 16 patients had the scapula fracture as the only lesion 47 patients had other lesions in addition Traffic accidents were the causing factor in 80 per cent of the cases

The results were examined after an average observation time of 5½ years One patient died during the observation time The patients were questioned about pain in the shoulder and were examined for mobility

It appeared that 38 patients were without pain 17 patients had slight pain and 7 patients had severe pain 50 patients had free movement 6 had slightly impaired function and 6 had severely impaired function of the shoulder The poor results regarding both pain and function were seen in patients with fractures through or close to the shoulder joint Fractures of the clavicula neck or shaft of the humerus did not influence the results 4 patients (2 with paralysis agitans 1 with cancer metastases to the scapula and 1 with previously operated cervical disc herniation) showed poor results

FOUR SEGMENT FRACTURES OF THE HUMERAL NECK

S Pilgaard & A Øster (Arhus Denmark)

A study of 21 four segment proximal fractures from the County Hospital and Municipal Hospital in Arhus re examined from 5 months to 15 years after the accident is presented. Half the patients were more than 60 years of age at the fracture sustaining Four were treated by closed treatment 17 were operated upon (in three cases the humeral head was removed four were Rush nailed one was treated with cerclage only three with Lane or AO plates and six received primarily the Neer prosthesis)

Closed reduction was found inadequate for active healthy patients in which case open reduction was preferred In open reduction the best results were obtained in the patients treated with Rush nailing plates or Neer prosthesis Avascular necrosis of the detached head was uncontrollable

The conclusion was that in four fragment fractures of the proximal humeral neck operative treatment is of value According to our results it seems that the methods with Rush nailing plates and prosthesis have the same range of success It is finally stressed that the four segment classification mentioned in 1934 by Codman and later adopted by Charles S Neer is important for the choice of treatment and the evaluation of the results

PROXIMAL HUMERAL FRACTURES

Olof Ahlgren & Helge Appel (Umeå Sweden)

Fifty proximal humeral fractures treated at University Hospital in Umeå Sweden were followed up Observation time was more than one year The fractures were classified in four groups according to the number of fragments and degree of

dislocation On the one hand the result of [illegible] patient s view of his own conditi n [illegible] of C. S Neer

It is surprising how often the patient [illegible] Most of the poor results were found among [illegible] four part fractures) Concerning this t [illegible] extensive use of prosthetic reconstruction [illegible] located three part fractures) gave [illegible] however very difficult which is why [illegible] Fractures of type II (dislocated two-part [illegible] some problems especially if the primary [illegible] type I (all proximal humeral fractures [illegible] number of lines of cleavage) gave no greater [illegible]



Figure 1 Anatomical landmarks for the identif[illegible] the scapula

The investigation shows results of simple reconstruction of old lesions after ankle joint distortions to be good

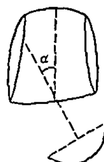
THE ANATOMY OF THE TALUS IN CLUBFEET RESULTS OF AN ARTHROGRAPHIC STUDY

A Hjelmstedt & B Sahlstedt (Uppsala Sweden)

In autopsy studies of congenital clubfeet most authors describe a pronounced deformity of the talus The question then arises as to how often talus deformity occurs in clinical series and how it varies The talus can be well delineated by arthrography of the talocrural and talonavicular joints Arthrographic studies with standardized technique on 30 autopsy specimens of normal feet show a good correlation between the X ray findings and the specimen itself

A clinical study was performed on 24 congenital clubfeet in 18 patients and in 8 clubfeet in 5 patients with neurological disorders Arthrography was repeated in 17 clubfeet The median age at the first examination was 5 months and 3 years respectively

In both groups the anatomy of the talus varied from within normal range to pronounced deformity of the same kind as reported from autopsy studies The degree of medial deviation of the head is given in Figure 1 The plantar deviation of the head was not so pronounced The curvation of the trochlea varied from normal to rather pronounced flattening in some cases of congenital clubfeet and *further to extreme flattening in some of the neurological cases* The recesses of the talocrural joint were often partially or totally obliterated



Normal angle
of deviation
α ≈ 15 – 6

Medial deviation of the head	Congenital	Secondary
5 — 24	3	2
25 — 44	9	1
45 — 64	12	5
Total feet/patients	24/18	8/5

Figure 1

DEVELOPMENT OF THE TIBIO FEMORAL ANGLE DURING GROWTH

P Salenius & E Vankka (Helsinki Finland)

The authors have investigated 1480 pairs of knees of children at different ages from newborns to 16 years with intervals of half a year The results have been expressed as an angle between tibial and femoral longitudinal lines and given as degrees of varus or valgus correspondingly The angles as degrees have then been analysed with the help of a computer The aim of the investigation has been to find out the typical tibio femoral angle for each age group The result of the investigation is given in the figure, in which it can be seen that at birth there is a pronounced varus which at the age of about 1 year 8 months changes to valgus reaching its highest values at the age of three years Sometimes the degree of valgus can be as high as 25 and be corrected by itself during growth In the mean the valgus returns from about 10 at the age of three years to about 5–6 later when it then stabilises An operative correction is therefore very seldom indicated

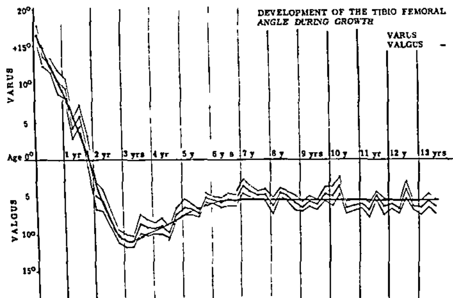


Figure 1 Development of the tibio femoral angle during growth as estimated with the computer on the basis of 1480 investigated pairs of knees The two lines represent the standard deviation between which the mean development is drawn freely

RECONSTRUCTION OF CRUCIATE LIGAMENTS USING MENISCUS

Bengt O V Tillberg (Harnosand Sweden)

Operation has more and more become the usual treatment in ligament injuries of the knee In fresh injuries it is usually possible to perform a primary suture with good result but the lesion is often overlooked In such cases a reconstruction

The investigation shows results of simple reconstruction of old lesions after ankle joint distortions to be good

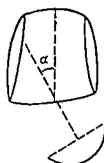
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In both groups the anatomy of the talus varied from within normal range to pronounced deformity of the same kind as reported from autopsy studies The degree of medial deviation of the head is given in Figure 1 The plantar deviation of the head was not so pronounced The curvation of the trochlea varied from normal to rather pronounced flattening in some cases of congenital clubfeet and further to extreme flattening in some of the neurological cases The recesses of the talocrural joint were often partially or totally obliterated



Medial deviation of the head	Congenital	Secondary
5 — 24	3	2
25 — 44	9	1
45 — 64	12	5
Total feet/patients	24/18	8/5

Figure 1

Table 1 Below knee amputations for ischaemic gangrenes by operative technique Number of patients mean ages occurrence of diabetes frequency of re amputations to above knee local revisions and delayed healing only Lund 1966–1971

Technique of below knee amputation	No of patients	Mean age	Rate of diabetics	Re amputations to above knee level	Local revision only	Delayed healing only
Sagittal (medial and lateral flaps)	58	73 9	18/58 (31 %)	6/58 (10 %)	3/52 (6 %)	6/49 (12 %)
Conventional (anterior and posterior flaps)	41	73 7	23/41 (56 %)	16/41 (39 %)	2/25 (8 %)	6/23 (26 %)

has induced changes in techniques as the posterior flap technique (Gormley 1947) and the one presented here similar to the technique of Tracy (1966)

The sagittal technique is an alternative way to reduce the amount of pretibial skin still giving two symmetric flaps and well shaped stumps Medial and lateral musculo cutaneous flaps Tibia cut by saw in a 45 angle to support the myoplasty and conform to the shape of the stump No drill holes and no osteo plasty The muscles and the fascia are sawn from side to side with Supramid and the skin with 4–0 atraumatic nylon resulting in a sagittal scar No bloodless field and no drainage Penicillin prophylax is given Plaster above knee for two weeks

In ischaemic gangrenes with or without diabetes the attempted below knee ampu tation was 93 per cent and the achieved below knee level was 82 per cent of the total amount of below and above knee operations during 1971

THE LOW PRESSURE LEG IN OBLITERATIVE VASCULAR DISEASE

P Holstein (Copenhagen Denmark)

In obliterative vascular disease the blood pressure in the arterial tree distal to the occlusion is maintained at a lower level than that of the aorta

Measuring of distal blood pressure is highly informative concerning the degree and the level of occlusion We have measured the distal arterial blood pressure by two methods Both are indirect The first method employs a mercury strain gauge as detector as described by Strandness & Bell By placing a cuff proximal to the detector we can measure the blood pressure at the level of the cuff We measure the blood pressure at the first toe the ankle the calf and at the thigh

Concerning amputation in obliterative vascular disease the condition of the skin is of particular importance We measure the cutaneous perfusion blood pressure A solution of Xenon 133 or Antipyrine labelled with J^{131} or J^{125} is injected intra *dermally* A small amount of histamine in order to produce local vasodilatation is added The depot is covered by a cuff and the cutaneous blood pressure can be

measured as that external pressure which is sufficient to arrest the wash-out of the isotope The method is described by Lassen & Westling

It is our experience that healing of a surgical wound or an ischemic ulcer demands a cutaneous perfusion pressure above 15–20 mm Hg In performing below knee and above knee amputation distal to an arterial occlusion we have found a considerable increase of the cutaneous blood pressure in the amputation stump This is fully in accordance with the law of Poiseuille

ARTHRODESIS OF THE FIRST METATARSO PHALANGEAL JOINT

B Næs & A Rugtveit (Oslo Norway)

100 feet with hallux valgus half of which were operated with sucapital osteotomy (Hohmann) and the other half with arthrodesis of the metatarso phalangeal joint constituted the material Mean observation time in both groups was 31 months

Before operation mean valgus position of the big toe was 49 in the arthrodesis group and 36 in the Hohmann group In 41 and 25 feet respectively metatarsalgia was present The average age was higher in the arthrodesis group

The subjective valuation of the treatment was approximately equal for the two operations In both groups there were ca 10 per cent bad results (unchanged or worse)

The number of feet with metatarsalgia was reduced by 66 per cent after arthrodesis compared with 28 per cent after Hohmann s operation this in spite of the fact that in all the worst cases of metatarsalgia arthrodesis was performed

Further when no special procedure was used to relieve the metatarsalgia (such as excision of painful metatarsal heads) arthrodesis had a clear effect on the metatarsalgia

The effect on metatarsalgia in the Hohmann group was related both to the shortening of the first metatarsal bone and to the postoperative valgus of the first toe

Conclusions

1 Arthrodesis of the first metatarsio phalangeal joint increases the probability of curing metatarsalgia with hallux valgus
2 The functional results after arthrodesis equals those after Hohmann s operation both subjectively and objectively

BONE RESEARCH

EXPERIMENTAL OSTEOPOROSIS

J A Sevastikoglou (Umeå Sweden)

This is a short report of the main studies on generalized experimental osteoporosis carried out in recent years in the Orthopaedic Research Laboratory in Umeå *Adult male Sprague Dawley rats maintained on a low-calcium normal* phosphorus diet with adequate amounts of total protein and vitamin D have been used throughout

After about 6 months the skeleton of rats treated as above from 1 week up to 12 months underwent significant ma reduction The remaining bone ha I n rmal

structure degree of mineralization and chemical composition Increased serum and bone 45Ca specific activity normal or decreased bone accretion and occasionally subnormal serum calcium levels were also registered

Similarly treated rats showed significantly increased parathyroid volume and function as compared with normal animals Significant variation of their serum calcium level was observed There was a coincidence of periods of parathyroid hyperfunction and decreased serum calcium level These observations were thought to indicate that osteoporosis was in this case connected with parathyroid hyper function However previously thyroparathyreoidectomized rats maintained on the low-calcium diet for 6 months developed the same type of osteoporosis as the intact rats It seemed therefore that prolonged low calcium intake induced osteoporosis in the adult rat also in the absence of the parathyroids

Fluoride given in 0 01 and 0 02 g/kg body weight in rats maintained on the low calcium diet for 6 months did not prevent the development of osteoporosis When after 6 months on the low calcium diet the rats were given a high calcium diet for another 6 months certain indications of reversibility of the skeletal changes were observed towards the end of the observation period

References

S E Larsson (1969) *Acta orthop scand* Suppl 120

VITAL MICROSCOPY OF BONE AUTOGRAFTS IN THE RABBIT EAR CHAMBER

In vivo fluorescence of tetracycline labelling

Finar Sudmann (Oslo Norway)

To be published in *Acta Orthopaedica Scandinavica*

EXPERIMENTAL HETEROTOPIC OSSIFICATION IN THE ISCHEMIC RAT KIDNEY

T Sam Lindholm Ralf V Lindholm & Robin Hackman (Helsinki Finland)

It is known that Ca salts precipitate in injured or dead tissue and that bone can be formed in soft tissue without any direct connection with the skeleton Transitional epithelium of the urinary tract has been shown to induce bone formation in adjacent connective tissue

By unilateral ligation of the renal vein and artery an ischemic state was produced in rats The histological changes in the ischemic kidneys were then studied by hematoxylin eosin and van Kossa staining and by using microradiography oxytetracycline fluorescence 45 Ca autoradiography and electron probe microanalysis

The weight and sectional area of the ischemic kidneys decreased successively (Figure 1) Ingrowth of inflammation cells and beginning fibrosis in the papilla were found on the 22nd day Calcification as seen after v Kossa staining started subcapsularly and reached a maximum on the 72nd day Oxytetracycline fluorescence roentgen density in the microradiographs and incorporated 45 Ca were maximal at about 100–150 days after ligation (Figure 2 and 3) Trabecular bone was found on the 91st day in close contact with strings of epithelium According to electron probe microanalysis the osteoid areas contained Ca and P in the same amounts as normal bone

When formation of fibrous tissue and ingrowth of transitional epithelium in the papilla and the simultaenous subcapsular calcification have taken place trabecular bone is formed from connective tissue cells without any intermediate cartilagineous stage

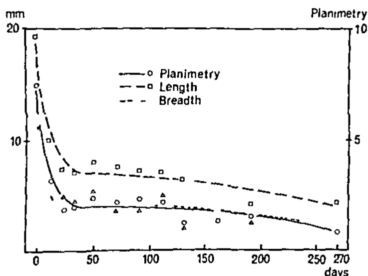


Figure 1 Length breadth and section area of the ischemic kidneys as function of time

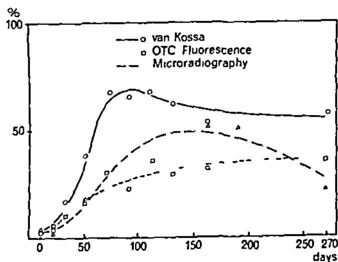


Figure 2 The calcified areas of kidneys sections demonstrated by the v Kossa staining method tetracycline fluorescence and by microradiography

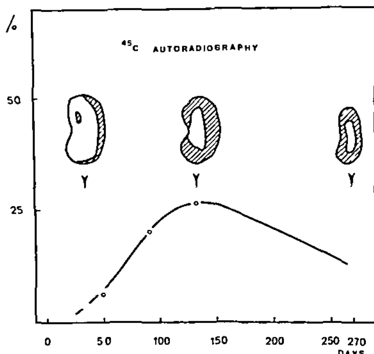


Figure 3 The calcified areas of kidney sections demonstrated by ^{45}Ca autoradiography

QUANTITATIVE DETERMINATION OF GROWTH STIMULATING EFFECT OF GROWTH HORMONE

Lars Ingvar Hansson & Karl Goran Thorngren (Lund Sweden)

Method

Female rats were hypophysectomized at the age of 60 days Administration of growth hormone and thyroxin started 15 days postoperatively With the aid of the tetracycline technique the growth from the proximal growth plate of the tibia during the first 15-day period and the following 20-day period was registered

Group A Thyroxin 5–40 μg/kg daily for 20 days
Group B Growth hormone (bovine–NIII) 25 μg/daily for 20 days
Group C Growth hormone as in group B combined with thyroxin as in group A
Group D Bovine ovine and human growth hormone 1–400 μg/daily for 10 days combined with thyroxin 20 μg/kg daily

Results

A Thyroxin had a growth stimulating effect which was optimal at 10–20 μg/kg daily The accumulated growth amounted to 300 μ compared to 20 μ without thyroxin

B Growth hormone for 20 days resulted in f00 μ
C The optimal dose of thyroxin was the same as in A and the growth amounted to 1100 μ a synergistic effect
D 25 μg bovine growth hormone daily resulted in 600 μ and 100 μg in 1100 μ The effect of bovine and human growth hormone was lower The effect of thyroxin amounted to 200 μ

Conclusion

Growth hormone and thyroxin have a stimulating effect on the longitudinal bone growth in hypophysectomized rats Combined administration of thyroxin and growth hormone has a synergistic effect The biological activity of various doses of growth hormone and of various growth hormone preparations is possible to quantitate

THE INFLUENCE OF OESTRADIOL-17B UPON COLLAGEN SYNTHESIS IN FEMURS OF CASTRATED FEMALE RATS

A *Langeland* (Oslo Norway)

Young adult female rats about 170 g body weight were castrated and from the day of operation given daily intramuscular injections of 0 5 1 0 2 0 5 0 10 0 and 20 μg oestradiol 17β respectively One group of castrated and one group of un *castrated rats of the same body weight served as controls and received injections* of the vehicle only Twenty four hours before being killed the rats received 25 μCi proline C-14 intraperitoneally

The rats receiving 1 and 2 μg oestradiol pr day had a significantly lower dry weight of femur than the controls and than these receiving 5 10 and ?0 μg On the other *hand the rats receiving 1 μg oestradiol pr day had the highest hydroxy* proline C 14 specific activity (SA) while those receiving 10 and 20 μg pr day had the lowest SA

The rats receiving 1 and 2 μg oestradiol pr day seem to have had both the highest collagen synthesis rate and the highest collagen resorbtion rate At the highest doses of oestradiol there may have been a reduced collagen turnover and especially a reduced resorbtion The hydroxyproline SA/proline SA ratio were reduced when the rats received 10 and 20 μg oestradiol pr day

NORMAL REPAIR OF ORTHOTOPIC AUTOLOGOUS CANCELLOUS BONE GRAFTS

P O Gronblom & *P Slätis* (Vasa Finland)

In 36 adult rabbits cylindrical cancellous bone grafts were obtained with a specially designed punch out instrument transversally from the metaphysis of the femur and axially from the tibial condyle The grafts which extended throughout their respective bones were lifted out and subsequently treated in two ways In one group of animals the cylindrical graft was reinserted in the other the cancel lous bone was crushed prior to its replacement into the donor site The progress of repair was evaluated by a triple fluorochrome labelling technique and fluor escence microscopy in addition to ordinary histological procedures The animals were killed 1 2 3 6 and 1f weeks after the operation

Cancellous bone grafts with the trabecular structure intact revealed scanty fluorescence in the marginal parts of the cylindrical block whereas the central part of the graft remained unlabelled Thus the areas of the graft closely facing surrounding vital cancellous bone retained their viability Two weeks after the operation bone bridges were discernible between the surrounding bone and the graft New bone was *laid down along the previous cancellous bone which served as a* scaffolding lattice work for invading tissue The repair proceeded centripetally until the entire graft was incorporated

The process of repair was more rapid where the trabecular structure of the graft had been left untouched

THE REPAIR OF BONE DEFECTS WITH FREE PERIOSTEUM

I *Ritsila* & S *Alhopuro* (Helsinki Finland)

Controversial views of the osteogenic capacity of free periosteal grafts are still prevalent in the literature Perhaps it is because of this confusion that free periosteum has had no clinical use today In our earlier experiments constant bone formation was observed in autogenous periosteal grafts transplanted to experimental locations *In the present study this strong bone forming capacity of free* periosteal transplants is used to repair different kinds of bone defects Experimental defect in the calvarium of a growing rabbit could be reconstructed with this material and after two months the bony healing of the defect was complete Ulnar shaft defect has been another model A part of the ulnar shaft of a growing rabbit was resected and free fat transplant was placed as an interposition material to prevent the healing of the defect After two months this fat could be taken away and the bone defect was ready for studying different kinds of bone transplants Free periosteum formed a strong bony union over the defect The physiological maxillary defect in the palatal bone of a growing rabbit has also been a location for periosteal transplantation The defect could be filled with bone with this method but simultaneous growth disturbance of the upper jaw occurred This proved to be due to the stapling of the premaxillo maxillary suture

Based on these studies free periosteal grafts have been used in the Finnish Red Cross Plastic Surgery Hospital (Chief Surgeon Aarne Rintala) in the primary repair of the congenital maxillary clefts in cleft palate children Free periosteum from the anterior side of the tibia has been transplanted across this defect Good bone formation has occurred and by this method it has been able to stabilize the loose alveolar segments and give rise to a solid symmetrical alveolar arch

THE EXPERIMENTAL ELIMINATION OF PARTIAL PREMATURE EPIPHYSEAL CLOSURE

K *Osterman* (Helsinki Finland)

Trauma to the epiphyseal growth plate of a child provoking a bone bridge between the epiphysis and metaphysis often causes growth disturbances of a leg When treating deformities like this the bone bridge has been left intact (Salter et al (1963) *J Bone Jt Surg* 45 A 578) Recent clinical observations (Langenskiold (1967) *Acta orthop scand* 38 2?7) encouraged investigating whether it is possible experimentally to normalize growth by removing the bone bridge surgically

The distal femoral growth plate of a rabbit was partially destroyed and when angulation appeared the bone bridge was removed. To prevent a new bridge the hole in the bone was filled with different interposition materials or no material at all. The other femur was a control. 178 animals were used and the results were analyzed using X-ray, histology and tetracycline labeling. The results show that it is possible to prevent progression of deformity by removing the bone bridge. By using interposition materials it is possible to prevent the recurrence of bone bridges and to produce correction of deformity. The best results were reached by using dead cartilage as interposition material. The results of this study support the view that in selected clinical cases the operative elimination of a bone bridge between the epiphysis and metaphysis and filling the gap with some interposition material are indicated. The detailed results of this study will be published later.

DISCUSSION

A. *Langenskiöld* (Helsinki, Finland)

Österman has built a firm experimental basis for the operation I described in 1967 (*Acta orthop. scand.* 38, 267). During the last two years seven patients have been operated on by this method for partial epiphyseal closure. The results are very encouraging. The operation should be carried out under a microscope. It can be recommended for general use. The results are quite in accordance with my investigations concerning the growth mechanism of the epiphyseal plate carried on over the last twenty-seven years.

HAND SURGERY

PRIMARY MOBILIZATION AFTER SECONDARY FLEXOR TENDON SURGERY

G. *Bakalim* (Helsinki, Finland)

At the Department of Orthopaedics and Traumatology, Helsinki University Central Hospital, primary mobilization after secondary flexor tendon surgery has been used for two years. It is a condition that the graft should be adequately fixed. Distally the graft is carried through a canal drilled from the distal phalanx to the upper side of the nail and the fixation is reinforced by a knot tied in the transplant. Some metal sutures are applied to prevent undoing of the knot (Figure 1). Proximally Pulvertaft's technique is used. The graft is carried twice through the ruptured end of the flexor tendon. Anastomosis is carried out at the level of the m. lumbricalis. As a rule the tendon of the m. palmaris longus is used as graft, otherwise the long extensor of the toes. A reinsertion is made wherever possible. Volar transverse incisions over the finger joints give a good cosmetic result. The scars do not show and the pulley mechanism is not injured.

The end results have been classified according to active flexion of the interphalangeal joints, "good" meaning that the distal crease of the palm is reached with the finger tip. An extension deficiency by 30° or more places the result one class lower. A condition for a good result in the thumb is that mobility should be at least 50 per cent of the normal. Moreover a good pinch is required. The end results in the total series are shown in Table 1: good 57/93 (61 per cent), fair 22/93 (24 per cent), poor 14/93 (15 per cent). The results for the thumb and ring finger

were [illegible] The [illegible] presence of [illegible] injuries. The [illegible] 16-20 years. [illegible] poorest. [illegible] (97/[illegible] [illegible] results may be [illegible]

Finger	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Good	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fair	[illegible]	[illegible]				[illegible]
Poor	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SU[illegible]

For [illegible] The [illegible] was [illegible]

In [illegible] the [illegible]

In one case active elbow extension could be obtained by use of a part of the deltoid permitting the patient to move from chair to bed without assistance which was impossible before surgery

Results are here shown in a film

AFFERENT IMPULSES AND HAND PROSTHESES

F Moberg (Gothenburg Sweden)

My work with C5–C6 paraplegias has taught me that the important grip function in high degrees of lost hand function is the key grip not the three pulp pinch. Afferent impulses is the leading factor The second is broad soft gripping surfaces with friction The key grip is also more cosmetic than the three pulp pinch never used by a resting hand

In work the triceps of a cat has some 50 000 afferent and efferent impulses/sec—a hand certainly much more A prosthesis has perhaps 3–4 efferent non afferent impulses

Obviously a major change in the practical value of hand prostheses must now be based on the supply of afferent impulses to the patient s conscious mind This is possible since I was able to prove that cutaneous receptors are able to register in a normal way passive motion and position of moving limbs the receptor system in muscles tendons and joints being excluded Thus from an artificial finger the factors mentioned can be linked up with skin far away and a system of functional afferent impulses can be created Tests are going on with other factors A simple key grip model hand prosthesis was demonstrated

Progress must be built upon close cooperation between technology and the hand surgeons who have so far hardly contributed enough

DISCUSSION

Knud Jansen (Copenhagen Denmark)

The research in hand function control sites and priority of finger movements form an important part of the recent research programme within prosthetics It is general experience that the specialised devices offer optimal capacity

Mr Cerman s hand from the Netherlands does offer the movements required by Erik Moberg

Other research work has investigated the mechanisms of proprio and of ecteroception

For the below elbow amputee the mechanical prosthesis is still the most useful

LATE RESULTS OF 137 NEURORRHAPHIES IN UPPER EXTREMITIES

U Kankaanpää & G Bakalim (Helsinki Finland)

Altogether 137 neurorrhaphies were performed for 96 patients in the upper extremities between the fingers and the upper arm This series consists of cases treated at the Department of Orthopedics and Traumatology University of Helsinki Central Hospital during the years 1960–1969

The nerve lesions were distributed between various nerves as follows median 99 ulnar 23 superficial radial 1 hand and finger nerves 85

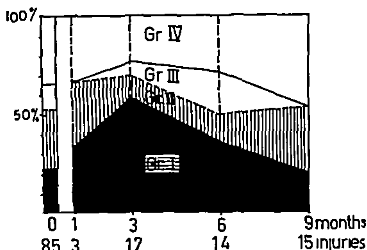


Figure 1 The effect of suture delay on the results evaluated by 2 point discrim test 0 = primary suture

The average follow up time was 4 years 11 months (1 to 10 years)

In 62 patients the lesions were cuts (including 7 attempts of suicide) 33 patients had crush injuries

Only the results of 2 point discrimination (2 pd) are presented here The results were classified as follows Group I – 2 pd 0–6 mm Group II – 2 pd 7–15 mm Group III – 2 pd 16–20 mm Group IV – 2 pd over 20 mm

The proportion of Group I in the case of each of the various nerves was median nerve 7/28 = 25 per cent ulnar nerve 3/23 = 13 per cent hand and finger nerves 29/85 = 34 per cent

The proportions of Group I were clearly related to ag i e it was reduced from 100 per cent in the age group 0–10 year olds to 15 per cent in the age group 51–60 year olds

There were 85 primary and 52 secondary suturations In the entire material the proportion of Group I was 21 per cent in the primary and 38 per cent in the secondary suturations These results were however opposite if the material was divided into lesions involving the forearm or wrist on the one hand and hand lesions on the other Thus it would seem that better results will be achieved by primary suturation in the area of forearm or wrist and by secondary suturation within the hand area (Figure 2)

One explanation for this is the fact that the proportion of crush injuries was 24 per cent in the area of wrist while it was 42 per cent in lesions involving hands and fingers

The effects of delayed suturation are shown in Figure 1 The proportion of good results was highest or approximately 59 per cent during a period ranging from 1 to 3 months following the original injury After this time good results became increasingly more rare their proportion being approximately 20 per cent one year after the injury

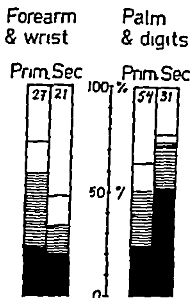


Figure 2 The results of primary a secondary suture of forearm nerves compared with those of palm a digits

RESTORATION OF PINCH GRIP IN TRAUMATIC PARALYSIS OF THE ULNAR NERVE

K A Solonen & G Balalim (Helsinki Finland)

This report is based upon operative treatment of 34 patients with loss or weakness of pinch grip due to traumatic lesion of the ulnar nerve The nerve was injured 6 months to 32 years earlier Surgical repair of the nerve had been impossible or unsuccesful Reconstruction of the mechanism for pinch grip was just a part of the total surgical treatment To restore the mode and strength of pinch tendon transfers for adduction of the thumb and abduction of the index finger were adopted Both the extrinsic extensors and flexors were used The functional results followed up for between 4 months and 8 years show a marked improvement both in dexterity and strength of the pinch In all but two cases the patients considered the hand more skillful than it was preoperatively

TREATMENT OF LUNATOMALACIA WITH DISTAL RADIUS SHORTENING

Rune Axelsson (Gothenburg Sweden)

The etiology of lunatomalacia has still not been solved There is statistical support only for that theory advanced by Hultén at the end of 19_0 the so-called minus variant of the ulna To eliminate that from the view of weight bearing unfavourable minus variant Hultén made osteotomy with shortening of the radius By placing the osteotomy proximally in the metaphysis however angulation of the osteotomy occurred and thereby a great limitation of the rotation of the forearm Hultén found however that the structure of the lunate was almost normal 3 years post

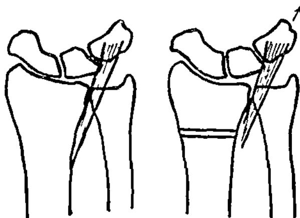


Figure 1 The oblique part of the dorsal radiocarpal ligament cut at the osteotomy of the radius

operatively and the patient was free from complaints except for the limitation of the rotation

By a series of anatomical dissection studies and bench experiments on wrist joint preparations in the beginning of the 1960 s I found that a transverse osteotomy of the radius placed as distally as possible so as not to disturb the distal joint between radius and ulna was the best one With the osteotomy in that part of the radius you have to cut the insertion of the oblique part of the dorsal



Figure 2 Man 36 years old with lunatomalacia in fragmentation stage Operation May 1968 distal radius shortening Already 3 months later the lunate shows normalization of its structure

radiocarpal ligament which reduces the weight bearing of the lunate Shortening of the radius is attained by removing a bone plate in the osteotomy The thickness of this plate is calculated on the degree of variant and in a case with normo variant the bone plate should not be more than 3-4 mm thick so as not to disturl the distal radioulna joint From my bench experiments I found that a steel wire through bore canals in a dorsovolar direction on each side of the osteotomy and an AO plate with screws both gave good stability without reduction of the shorten ing of the radius during the experiment I choose steel wire because it is much less metal to be implanted

With this operation procedure I have treated 19 cases with lunatomalacia during 1963-1969 The patients 5 women and 14 men were 19 to 6? years old with a mean age of 35 years at the operation The distribution of the variant of the ulna was preoperatively 9 minus 9 normo and no plus variant By the follow up with the average of 2 years postoperatively the distribution of the variant was 14 plus 5 normo and no minus variant The compression quotation of the lunate accord ing to Ståhl has an average increase of only 0 13 Concerning the healing of the lunatomalacia I found a normalization of the structure of the lunate in my cases in 37 per cent The patients had no complaints after the time of treatment and all the patients but two have been able to return to their preoperatively heavy jobs They have very little limitation of rotation and no complaints about it

The results have been encouraging and the complications which were easily dealt with have been very limited

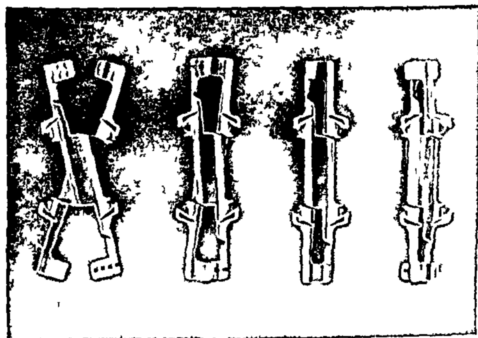


Figure 1 The under surface of the device open and in different positions of locking (For text see upper half of page 150)







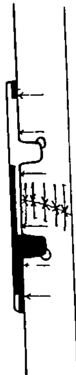




Figure 2 Drawings of the function of the instrument (For text see upper half of page 146)

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POSTOPERATIVE ORTHOPAEDIC INFECTIONS IN PATIENTS WITH DIABETES MELLITUS

LARS LIDGREN

Accepted 20 xii 72

In diabetes mellitus it is generally accepted that the resistance to in fections is decreased Thorough search of the literature failed to reveal any investigations of the frequency of postoperative locomotor system (orthopaedic) infections in diabetes in clean surgery The purpose of this investigation was to ascertain whether the incidence of post operative orthopaedic infections is higher in diabetics than in non diabetics This paper is one of a series based on an analysis of a 5 year material of orthopaedic infections encountered in a quarter million population

MATERIAL AND METHODS

During a 5 year period 1963 through 1967 all patients with orthopaedic infections at the Department of Orthopaedic Surgery Malmo General Hospital were subjected to analysis This 1 500 bed hospital is the only somatic disease hospital for the population of the city of Malmo (241 778 inhabitants in December 31 1963 and 254 338 inhabitants in December 31 1967) and is therefore suitable for an epidemi logical study (Lidgren & Lindberg 1972) The Department of Orthopaedic Surgery has 150 beds and is responsible for both classic orthopaedics and fracture surgery

From the beginning of 1965 data on all patients at Malmo General Hospital were stored in a computer so that it was possible to compare diabetics and non-diabetics regarding parameters such as sex age diagnosis type of operations and number of days in hospital From 1965 through 1967 a total of 3 617 clean orthopaedic operations were performed Of these patients 203 had diabetes mellitus

The frequency of postoperative orthopaedic infections after clean operations in diabetics was compared with non-diabetics The material is described in terms of age sex the anatomic localisation of the infection bacteriology and whether the infection affected the results of the operation

Only patients using parenteral insulin or oral tablets were included in the dia betic material

Material from infections was routinely obtained by swab for culture. Besides ordinary tests such as E.S.R. and temperature determinations were also made of the antistaphylolysin titer (ASTA) and C-reactive protein (CRP). All patients were examined roentgenologically.

RESULTS

Of 203 clean operations performed in diabetics 7 (3.4 %) were infected postoperatively. During the same time 3,414 clean operations were performed in non-diabetics. Of these 124 (3.6 %) were infected. Comparison between the frequency of postoperative infection in diabetics and in non-diabetics analysed with chi-square analysis showed $X^2 = 0.1$ ($p > 0.05$) and thus no demonstrable difference between the groups. There was no difference between the distribution of age and sex. Operations with long durations were not less frequent in diabetics compared with non-diabetics. However, only 2 arthroplasties with endoprosthesis were performed in diabetics compared with 70 in non-diabetics.

The mean age of the infected diabetics was 61 years. The ages of the patients in this group ranged from 40 to 82 years. There were 3 females and 4 males. The anatomic localisation of the infection was the hip in 5 cases, the lower leg in one and the foot in one.

Staphylococcus aureus was the pathogenic organism in 3 of 7 patients; in one patient culture gave growth of Escherichia coli, in one patient enterococcus and in one patient Staphylococcus albus. In 2 patients with negative culture the clinical picture together with high grade fever, high E.S.R. and positive serology gave the diagnosis of infection.

None of the orthopaedic infections were fatal but in two cases permanent disability could not be prevented despite antibiotic therapy. In one patient with trochanteric fracture of the femur the nail plate was removed before healing had occurred and in one patient with fracture of the tibia a chronic fistulating osteitis developed.

DISCUSSION

It is postulated that postoperative infections are prone to occur in diabetics (Dineen 1961, Forsham 1960). Schneiersen (1962) reported an increased frequency of infections in patients with uncontrolled diabetes with ketosis *but not among patients* with well-controlled diabetes. Animal experiments have indicated that healing is slower in uncontrolled diabetes (Rosen & Engquist 1960). In a study reported in *Annals*

of Surgery (1964) the incidence of surgical wound infection in 356 diabetic patients was 10 4 per cent i e significantly higher than the overall infection rate of 7 4 per cent but when the frequency was corrected for age it was the same as in non diabetics According to the literature diabetes mellitus also predisposes to bacterial arthritis but no supportive figures are given (Kelly et al 1965 Viel & Santelangelo 1962)

In the present material where the patients diabetes regulation was performed in intimate cooperation with internists and anaesthesiologists no difference was found in the frequency of postoperative orthopaedic infections between diabetics and non diabetics

SUMMARY

The frequency of postoperative infections following clean orthopaedic operations in non diabetics 3 414 patients with 124 infections did not differ from that in diabetics 203 patients with 7 infections

The patients are described in respect of age sex localisation of the infection and bacteriology The infections were never fatal but in 2 cases they spoiled the results of operation

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NEOPLASIA IN CHRONIC FISTULATING OSTEITIS

LARS LIDGREN

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Epidermoid carcinoma arising in chronic fistulating osteomyelitis is not common Schiewe & Koch (1967) reported a frequency of 0.38 per cent (72/18 760 cases) Selding & Fleming (1967) collected 102 cases with fistulating carcinoma including 90 from the literature 22 of these had regional or visceral metastases Metastasis later than 3 years after amputation have so far apparently not been reported When fistulating carcinoma spreads it is most often to the regional lymph nodes (74 per cent) Haematogenous dissemination is less common (Schiewe & Koch 1967) The average duration of the infection before development of carcinoma has been estimated at 30 years but cases with a latency of only 2.5 years have also been reported (Hejna 1965) Most of the carcinoma occur in the tibia and femur (Waldvogel et al 1971)

The number of cases of chronic osteitis and carcinoma an orthopaedic surgeon ever sees is small It was this rarity of the disease that induced me to report 3 cases seen at the Department of Orthopaedic Surgery in the last 2 years and to remind readers of the risk of chronic osteitis becoming malignant to be suspected if a change occurs in the clinical picture

CASE HISTORIES

Case 1

A 61-year-old man had haematogenous osteomyelitis proximally in the right tibia at the age of 8 He was initially subjected to sequestrectomy but later had frequent recurrences with suppurating fistulae treated with antibiotics In 1960 the lesion began to increase successively Roentgen examination suggested progression and the patient was first referred to the Department of Plastic Surgery where the lesion was found to be 15 by 7 cm surrounded by hyperkeratosis up to 2 cm thick On July 1 1960 the patient was operated upon with local excision and sequestrectomy and covering of the skin with a pedicle Histologic examination of a biopsy specimen of tissue from the margin of the operative wound showed sign

of squamous epithelial carcinoma Two weeks later the femur was amputated at the Department of Orthopaedic Surgery The patient was fitted with a suction prosthesis and after 2 months training he could use the limb properly and return to his usual work Today 2 years later the patient has no demonstrable signs of metastasis

Case 2

A 61 year old mentally retarded man with congenital clubfoot had had sores on both feet for 15 years With the aid of his relatives he has treated the sores himself at home The patient was first admitted to the Department of Medicine when the condition progressed At this time there were widespread fistulae in the right foot and a small ulcer near the lateral malleolus of the left ankle joint Roentgen examination showed extensive destruction of the right cuboid bone os cuneiforme tertium and the proximal parts of metatarsals III–V On the left side there was bone destruction of the fifth metatarsal and the proximal and middle phalanges of the fifth toe The patient was therefore transferred to the Department of Infectious Diseases where he was treated topically and systemically with antibiotics The ulcer on the left foot healed A biopsy specimen of granulation tissue from the right foot suggested well differentiated squamous epithelial cancer Because of this finding and the fact that the infection was refractory a B K amputation on the right leg was performed in February 1972 Microscopic examination revealed exuberant growth of squamous epithelial cancer in the fistulae After the operation the patient has shown no signs of metastases but he now has an exacerbation with fistulation in the left foot

Case 3

An 83 year old woman had haematogenous osteomyelitis in the proximal part of the left tibia at the age of 11 She was initially subjected to sequestrectomy but at intervals of a few years the infections recurred with suppurating fistulae In 1971 however the discharge increased and on two occasions the patient was admitted to the Department of Infectious Diseases for treatment In December 1971 it was noticed that the ulcer had widened and that the granulations were more exuberant A deep incision was made on two occasions and in February 1972 a biopsy specimen was obtained Histologic examination showed an anaplastic tumour Soon afterwards the tumour rapidly increased in size and caused increasing pain March 1 1972 the patient was admitted to the Department of Orthopaedic Surgery with a 5 × 6 cm exophytic tumour (Figure 1) whose margin could not be distinguished from the underlying bone Roentgen examination now showed increasing bone destruction underneath the tumour (Figure 2) Owing to rapid growth of the tumour it was considered radiosensitive and was treated with high voltage radiation at the Department of Radiotherapy The patient then had no signs of metastases but in March the tumour spread rapidly both regionally and viscerally Fine needle aspiration biopsy specimens of several lymph node stations showed growth of an anaplastic tumour a histological picture in accordance with reticular cell sarcoma (Figure 3) The patient died at home on March 24 1972 autopsy was not performed





Figure 1. Photograph showing growth of an exophytic tumour in sinus over proximal part of the left tibia.

Figure 2. X ray of the left knee showing the bone destruction underneath the tumour.

Figure 3. Fine needle biopsy from a cutaneous tumour showing disseminated malignant cells with sparse cytoplasm and nuclei with prominent nucleoli. Magnification × 800.

DISCUSSION

Pain, increased suppuration, spreading of the lesions with increasing granulation, roentgenologic signs of advancing bone destruction are signs suggesting that a chronic infectious fistula is becoming cancerous. Sometimes recurrence of the infection is in itself sufficient to reveal squamous epithelial cancer, especially if it is located deep in the sinus tract. If biopsy is done, specimens should be obtained from

several sites preferably with radical removal of the fistula after preoperative fistulography and injection of methylene blue If epithelial cancer is demonstrated the limb should be amputated without delay In series where treatment was confined to local excision a mortality of about 50 per cent has been observed (Schiewe & Koch 1967) Biopsy specimens should be obtained of palpably enlarged regional lymph nodes In about 70 per cent of such cases the enlargement of the lymph nodes is due to chronic inflammation the remaining cases with metastases should be treated with combined lymphadenectomy and radiotherapy Also other types of complicating malignant changes have been seen in patients with chronic osteitis *vi* fibrosarcoma (Waugh 1952) adenocarcinoma (Buxton 1954) basal cell cancer (Dalmonte 1953) and plasmocytoma (Heilmann 1957) but the association with reticular cell sarcoma (case 3) has not been noted previously

According to the literature chronic fistulating osteitis becomes malignant in about 0 4 per cent of all cases and then several decades after the onset of the osteitis The frequency of metastasis in such cases is about 20 per cent if the limb is amputated early but as high as 50 per cent if the condition is treated with local excision only

SUMMARY

Two cases of squamous epithelial cancer and one of reticular cell sarcoma in chronic fistulating osteitis are described

Malignant degeneration should always be suspected when there is a change in the clinical pattern in cases of chronic fistulating osteitis and histological investigation should routinely be performed

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ELECTRON DIFFRACTION EXAMINATION OF THE GROWTH ZONE OF THE EPIPHYSIS

G Lenárt I Veres G Bidló & L Kéry

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The most important feature of the electron diffraction examination is the use of electron beams for the special analysis of ultrastructure With this method it is possible to examine a few hundred Angstrom thick sections of bone both from the crystallographic and morphological viewpoints

The electron diffraction has definite advantages compared with the X ray diffraction previously used for ultrastructural analysis of the bone With X ray diffraction only a greater volume of bone could be investigated which is allways inhomogeneous and contains various phases of bone development and destruction (Lenart et al 1972) Electron diffraction on the other hand is suitable for examination of nearly homogeneous layers of bone showing only this or the other phase of mineralogical development of the bone (Lénárt et al 1971) This is because the ultrathin sections contain only one or a few bone crystals mostly in the same phase of development or destruction

The greatest difficulty in the examination of epiphyseal mineralization is also the inhomogeneity of the growth zone of the epiphysis i e the most important area of the ossification In this zone various phases of bone formation comprising cartilaginous parts and bone tissue in the early and later stage of mineralization can be found intermingled in a relatively small area

In the past the crystallographical examination of this zone was also based mainly on the X ray diffraction method (Lénárt et al 1971) The disadvantage of this method was that the analysis of this rather heterogeneous zone could be performed *in toto* only and so it did not

render possible a detailed examination of the various phases of the physiological mineralization.

The distinct analysis of these phases was solved by using electron diffraction as described above. By this method it is possible to examine from the crystallographical viewpoint strata of 400–600 Å thickness in the growth zone of the epiphysis and to observe separately in these nearly homogeneous layers the different mineralogical phases of ossification.

MATERIAL AND METHODS

The growth zone of the proximal tibial epiphysis of 3 month old calves was used for the examination. After excision the samples were freeze dried and embedded in Durcupan. The transversal ultrathin sections were prepared on a Reichert ultramicrotome by using glass knives. The section thickness was about 400–600 Å. A Tesla BS 242 electron microscope was applied at an accelerating voltage of 60 kV and a maximal resolving power of 20–25 Å. Kodak Bromid Lantern I 10 plates of especially high contrast were used; they were advantageous for the detection of diffraction lines and diffraction points.

In order to evaluate diffraction patterns the diameter of the rings as well as of points of symmetrical localization (2 r) were measured. The length (L) of the tube and the wave length (λ) were reckoned from calibration photos. Col I powdered in vacuum served as calibration material. The calculation was based on Bragg's formula $d = \frac{L\lambda}{r}$ where d is the interplanar spacing and r the radius of the diffraction ring.

RESULTS

At the assessment of the results it must be taken into consideration that the main question of bone crystallography is still the decision of the problem whether bone contains hydroxylapatite ($Ca_5(PO_4)_3OH$) alone, other calcium phosphates as well, or a mixture of these compounds (e.g. brushite $CaHPO_4 \cdot 2H_2O$, monetite $CaHPO_4$). If a greater amount of bone is examined, as occurs during the X-ray diffraction investigation, various kinds of crystals may be examined together. In this case the hydroxylapatite, being of greater quantity, may handicap the detection of other crystals which are possibly its precursors. With the use of electron diffraction this difficulty can be avoided.

The electron diffraction analysis of the growth zone of the proximal tibial epiphysis showed the presence of brushite (Figure 1, Table 1) and poorly developed apatite (Table 2) at the metaphyseal part of the zone.



Figure 1 Electron diffraction pattern of the metaphyseal part of the growth one

Table 1 The electron diffraction pattern of the metaphyseal part f the growth one shows the presence of brushite

dh k l A	Intensity
4 25	[illegible]
2 75	5
1 7?	2
1 52	2
1 35	?

Table 2 The electron diffraction pattern of the metaphyseal part of the growth one shows the presence of poorly developed apatite

dh k l A	Intensity
2 79	3
2 05	3

DISCUSSION

The difficulties in the interpretation of the diffraction [illegible] crystallography are well known (Munzenberg 1970 1971 [illegible]

The small number of diffraction lines in our cases [illegible] by the fact that the growth zone is an area in the very [illegible] lization and its crystallization has not yet reached th[illegible] of the fully developed bone mineral The mineral[illegible] scribed above supports the assumption that in th[illegible]

render possible a detailed examination of the various phases of the physiological mineralization.

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POWER SPECTRA OF MYOELECTRIC SIGNALS IN MUSCLES OF ARM AMPUTEES AND HEALTHY NORMAL CONTROLS

P Herberts E Kaiser R Magnusson & I Petersén

In recent years the method of controlling externally powered prostheses by means of myoelectric signals has received increasing attention Systems employing this method have been successfully designed and tested It is generally agreed however that the design of an optimum system requires an extended knowledge of the properties of the myoelectric signal

In most investigations of these signals considerable attention has been paid to the characteristics primarily the duration of individual muscle action potentials Action potential interference however, limits the application of duration measurements to weak muscle contractions only

In order to characterize the myoelectric signal at moderate and strong muscle contractions other methods must be used One such method is the measurement of the signal power spectrum Spectrum measurements have been reported by Richardsson (1951) Walton (1952) Krakau (1956) Fex & Krakau (1958) Hayes (1960) Larker (1960) Kogi & Hakamada (1962) Kaiser & Petersén 1963 and 1965 Sato (1965 and 1966) and Kopec & Hausman Petrusewicz (1966) A survey of the methods employed is contained in a paper by Kadefors et al (1968)

Information on the shape and variation of the myoelectric signal

This investigation was supported by the Swedish Council of Applied Research the Swedish Medical Research Council and the Insurance Company Folksam

power spectrum for muscles in healthy and normal individuals has been limited or nonexistent. Normal values obtained with the method used in the present paper, for instance, have been stated for the biceps brachii and orbicularis oris muscles only (Kaiser & Petersen 1965). Values for the muscles of amputees—in the stump region or elsewhere—have only been discussed briefly (Petersen 1966).

The purpose of the present investigation is to obtain detailed information on the power spectra of myoelectric signals from different muscles of arm amputees and controls. In our opinion such an investigation is essential for a proper evaluation of the applicability of myoelectric signals to prosthesis control.

MATERIAL

The power spectrum investigations were carried out for a series of 50 uninjured males as well as for a series of 30 male arm amputees, all aged between 20 and 50 years. The controls had not been subjected to neurological lesions or diseases, or severe accidents. In the control series the following muscles were examined: mm. trapezius, deltoideus, biceps brachii, brachioradialis, extensor digitorum communis, interosseus dorsalis I manus, vastus lateralis, tibialis anterior, soleus, gastrocnemius, and extensor digitorum brevis.

The series of arm amputees consisted of 30 males who had been operated upon during the period 1934–1966. Only patients amputated above and below the elbow were studied. Thus, no cases of exarticulations in the wrist, elbow joint or shoulder joint were included. The series comprised 7 patients amputated above the elbow and 23 patients amputated below the elbow. The majority of the patients had been amputated at ages ranging from 11 to 30 years. The amputations were performed 1 to 33 years—in 50 per cent of the cases 10 to 20 years—before the power spectrum investigations. Traumatic lesion was the cause of amputation in 27 cases, tumour in 2 cases and infection in 1 case. 17 of the patients had lost their left arm and hand and 13 their right. The following muscles of the forearm amputees were studied: mm. biceps brachii and brachioradialis, stump muscles on the extensor side of the forearm, and stump muscles on the flexor side of the forearm. Muscles studied on the above-elbow amputees were remaining stump muscles corresponding to mm. biceps brachii, triceps brachii, deltoideus and trapezius. Due to the great anatomical varia-

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EMG picture characterized by unusually smooth action potentials of—as estimated by inspection only—slightly increased duration (cf Petersen 1966)

METHODS

The myoelectric signals were picked up by means of coaxial needle electrodes having an external diameter of 0 65 mm (DISA Elektronik type 13 K 03) The needle electrodes were inserted essentially perpendicular to the direction of the muscle fibres with the tip of the needle at a depth of 0 5 to 1 cm in the muscle

In the case of uninjured controls signals from eight positions of the needle in nine muscles of the right hand side extremities were analyzed The muscles investigated were mm trapezius deltoideus biceps brachii brachioradialis extensor digitorum communis vastus lateralis tibialis anterior soleus and gastrocnemius The positions of the needle in the biceps brachii muscle shown in Figure 1, were carefully defined in accordance with a procedure developed by Kaiser & Petersén (1965) In this method the end plate zone of the muscle is located with the aid of electric stimulation by finding the point having the lowest threshold of stimulation Point 1 is situated in the end plate zone of the long head of the biceps 1 5 mm from the medial edge of the muscle Point 3 is the point having the lowest threshold of stimulation in the short head of the biceps Through this point a transversal line is drawn on which point 2 is situated 1 5 cm medially to the lateral edge of the short head Point 5 is located in the most distal part of the short head on the same longitudinal line as point 2 Point 4 is situated halfway between points 2 and 5 Points 6 and 7 are 1 5 cm distal and 1 5 cm proximal respectively to point 1 Point 8 is located as proximally as possible in the long head of the biceps

Needle positions in the other muscles were not defined with this great accuracy Still the needles were placed according to a consistent plan *viz* in two parallel rows of extensions and mutual distances adapted to the particular muscles Kaiser & Petersén (1965) have investigated the relative magnitudes of myoelectric signal power in octave bands centered at 50 200 and 800 Hz for the biceps brachii and orbicularis oris muscles The observations reported in the present paper include the octave centered at 1600 Hz also In addition to the nine muscles mentioned above five other muscles were investigated In 25 controls mm biceps brachii brachioradialis and extensor digitorum communis of the left side were examined In all 50 controls

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800 Hz octave and power in the 200 Hz octave over power in the 1600 Hz octave—provide a measure of the *shape* of the power spectrum

A block diagram of the experimental set up is shown in Figure 2 *The muscle action potentials are first amplified in a DISA electromyograph* the output of which is fed to a specially designed spectrum analyzer The amplification of the electromyograph was constant throughout the investigation and was adjusted to a value corresponding to a film recorder deflection sensitivity of 50 μV/mm The high pass filter time constant of the instrument was 1 second The spectrum analyzer contains a voltmeter measuring the r m s value of the unfiltered muscle signal and thus serving as a contraction level indicator

The spectrum analyzer also contains the four octave band pass filters and rectifiers mentioned above By means of a logarithmic amplifier and a switching system the four rectified signals are converted into three output voltages proportional to the ratios in dB of the power in the octave centered at 200 Hz to the powers in the octave centered at 50 800 and 1600 Hz respectively

The output voltages are presented as the positions of two bright spots the octave loci, on the screen of a cathode ray *oscilloscope* (Tektronix type 502) The horizontal deflections of the two spots are proportional to the 200 Hz/800 Hz and 200 Hz/1600 Hz activity ratios respectively The vertical deflections of both spots are proportional to the 200 Hz/50 Hz activity ratio All three deflection sensitivities were 1 mm/dB with associated over all time constants of 0.3 seconds

The three activity ratio voltages were not compensated for the differences in bandwidth of the four octave filters It follows that the indicated 200 Hz/50 Hz ratio was 6 dB above the true value the indicated 200 Hz/800 Hz ratio was 6 dB below the true value and the indicated 200 Hz/1600 Hz ratio was 9 dB below the true value We use the following notation for the various ratios

a = *indicated* ratio in dB of the activity (r m s value) in the reference octave centered at 200 Hz ("the 200 Hz band") to the activity *in the octave centered at 50 Hz ("the 50 Hz band")*

b = *indicated* ratio of the activity in the 200 Hz band to the activity in the 800 Hz band

c = *indicated* ratio of the activity in the 200 Hz band to the activity in the 1600 Hz band

α = a—6 = *true* ratio of the activity in the 200 Hz band to the activity in the 50 Hz band

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The output voltages are presented as the positions of two bright spots, the octave loci, on the screen of a cathode ray oscilloscope (Tektronix type 502). The horizontal deflections of the two spots are proportional to the 200 Hz/800 Hz and 200 Hz/1600 Hz activity ratios respectively. The vertical deflections of both spots are proportional to the 200 Hz/50 Hz activity ratio. All three deflection sensitivities were 1 mm/dB, with associated over all time constants of 0.3 seconds.

The three activity ratio voltages were not compensated for the differences in bandwidth of the four octave filters. It follows that the indicated 200 Hz/50 Hz ratio was 6 dB above the true value, the indicated 200 Hz/800 Hz ratio was 6 dB below the true value, and the indicated 200 Hz/1600 Hz ratio was 9 dB below the true value. We use the following notation for the various ratios:

a = *indicated* ratio, in dB, of the activity (r.m.s. value) in the reference octave centered at 200 Hz ("the 200 Hz band") to the activity in the octave centered at 50 Hz ("the 50 Hz band")

b = *indicated* ratio of the activity in the 200 Hz band to the activity in the 800 Hz band

c = *indicated* ratio of the activity in the 200 Hz band to the activity in the 1600 Hz band

α = a—6 = *true* ratio of the activity in the 200 Hz band to the activity in the 50 Hz band

800 Hz octave, and power in the 200 Hz octave over power in the 1600 Hz octave—provide a measure of the *shape* of the power spectrum

A block diagram of the experimental set up is shown in Figure 2 The muscle action potentials are first amplified in a DISA electromyograph, the output of which is fed to a specially designed spectrum analyzer The amplification of the electromyograph was constant throughout the investigation and was adjusted to a value corresponding to a film recorder deflection sensitivity of 50 μV/mm The high pass filter time constant of the instrument was 1 second The spectrum analyzer contains a voltmeter measuring the r m s value of the unfiltered muscle signal and thus serving as a contraction level indicator

The spectrum analyzer also contains the four octave band pass filters and rectifiers mentioned above By means of a logarithmic amplifier and a switching system the four rectified signals are converted into three output voltages proportional to the ratios in dB of the power in the octave centered at 200 Hz to the powers in the octave centered at 50, 800 and 1600 Hz respectively

The output voltages are presented as the positions of two bright spots the octave loci on the screen of a cathode ray oscilloscope (Tektronix type 502) The horizontal deflections of the two spots are proportional to the 200 Hz/800 Hz and 200 Hz/1600 Hz activity ratios, respectively The vertical deflections of both spots are proportional to the 200 Hz/50 Hz activity ratio All three deflection sensitivities were 1 mm/dB with associated over all time constants of 0 3 seconds

The three activity ratio voltages were not compensated for the differences in bandwidth of the four octave filters It follows that the indicated 200 Hz/50 Hz ratio was 6 dB above the true value the indicated 200 Hz/800 Hz ratio was 6 dB below the true value and the indicated 200 Hz/1600 Hz ratio was 9 dB below the true value We use the following notation for the various ratios

a = *indicated* ratio in dB of the activity (r m s value) in the reference octave centered at 200 Hz ("the 200 Hz band") to the activity in the octave centered at 50 Hz ("the 50 Hz band")

b = *indicated* ratio of the activity in the 200 Hz band to the activity in the 800 Hz band

c = *indicated* ratio of the activity in the 200 Hz band to the activity in the 1600 Hz band

α = a—6 = *true* ratio of the activity in the 200 Hz band to the activity in the 50 Hz band

β = b+6 = *true* ratio of the activity in the 200 Hz band to the activity in the 800 Hz band and

γ = c + 9 = *true* ratio of the activity in the 200 Hz band to the activity in the 1600 Hz band

For calibration of the spectrum analyzer we used four generators supplying sinusoidal signals of frequencies 50 200 800 and 1600 Hz respectively Each generator was fitted with an attenuator calibrated in dB Signals of the same amplitude (all ratios 0 dB) were simultaneously fed to the spectrum analyzer from the four generators and the cathode ray spot was adjusted to coincide with the screen s zero point The 50 Hz 800 Hz and 1600 Hz signals were then attenuated 10 dB and the oscilloscope gains were adjusted to produce coordinate changes of 10 mm on the cathode ray tube screen The coordinates obtained were independent of the absolute value of the voltages provided the latter were within the 50 dB linear range of the filter rectifier circuits The performance of the spectrum analyzer was also checked for input signals consisting of filtered and unfiltered Gaussian noise

The degree of muscle contraction was standardized with the aid of the contraction level indicator mentioned above The subjects were instructed to maintain for a few seconds the (moderate) contraction intensity yielding a specified voltmeter deflection During this period the locus coordinates were read—by the same person throughout the entire test series—from the screen of the oscilloscope

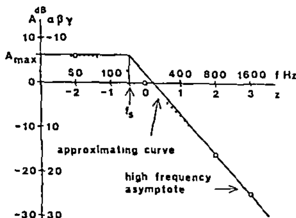


Figure 3 Piece wise linear model of power spectrum
(α = —6 dB β = 16 dB γ = 25 dB)

A detailed analysis of the measurement procedure (Kaiser et al., to be published) indicates that the over-all system rms error of the power spectrum values obtained is less than 1 dB. The random error component has a standard deviation of about 0.5 to 0.7 dB.

The three ratios α, β and γ define three points in the power vs frequency diagram shown in Figure 3. The fourth point shown in the diagram, at 200 Hz and 0 dB, is the reference point. The average power spectrum of myoelectric signals from a particular muscle passes through these four points. In order to give a simple piece-wise linear description of the shape of the power spectrum we have employed the following procedure.

A straight line, the high frequency asymptote, is passed through the two points at 800 and 1600 Hz. The slope of this line, s dB/octave, is the difference between the two ratios β and γ. The three points at 50, 200 and 800 Hz are connected with the curve

$$A = A_1 z + A_2 z^2 + A_3 z^3 \qquad (1)$$

where the independent variable z is normalized logarithmic frequency

$$z = \log f(\mathrm{Hz})/200 \qquad (2)$$

and the coefficients A_i are chosen in such a way that the curve has the same slope as the high frequency asymptote at 800 Hz.

$$A_1 = (\alpha - 9\beta + 4\gamma)/8 \qquad (3a)$$
$$A_2 = -(\alpha + \beta)/8 \qquad (3b)$$
$$A_3 = (\alpha + 7\beta - 4\gamma)/32 \qquad (3c)$$

The corner frequency f_c is defined by the intersection of the maximum level A_{max} of curve (1) and the high frequency asymptote. The values of A_{max} and f_c are as follows

$$A_{max} = A_1 z_{max} + A_2 z^2_{max} + A_3 z^3_{max} \qquad (4)$$

where

$$z_{max} = -(A_2 + \sqrt{A_2^2 - 3A_1A_3})/3A_3 \qquad (5)$$

(provided that $A_2^2 > 3A_1A_3$ and $A_3 \neq 0$)

and

$$f_c = 200 \cdot 2^{z_c} \qquad (6)$$

where

$$z_c = 2 - (\beta + A_{max})/(\gamma - \beta) \qquad (7)$$

The statistical analysis involved two types of comparison, viz. the comparison of several means and the comparison of a single mean with a hypothetical value or a difference between two means.

The former comparisons were performed by analyses of variance employing a hierarchical model with two levels. Individuals were considered as primary groups, muscles as secondary groups, and the separate measurements as replicates. Individuals were assumed to be a random effect and muscles a systematic effect. This means that individuals were regarded as a sample from a very great population, whereas "muscles" in the sample were the particular muscles in which we were interested in the present investigation.

This method was employed both for the uninjured controls and for the amputees in analyzing the difference between muscle means and also in analyzing means referring to the right and left side (in this case sides formed the secondary groups).

When these tests resulted in significant main effects, contrasts were analyzed by Tukey's T method. In all other cases, in which only one mean or the difference between two means was to be analyzed, the normal test was employed.

Throughout this study a 5 per cent level of significance has been used in the statistical tests.

RESULTS

Uninjured Controls

Muscles of the Right Arm and Leg

The mean values and standard deviations of the three ratios α, β and γ as well of the spectrum parameters s, f_t and A_{max} of nine muscles of the right arm and leg are shown in Table 1. The table also shows the correlation coefficients $r_{\alpha\beta}$, r_{α_t} and r_{β} between spectrum levels at 50, 800 and 1600 Hz.

Differences between the six parameter values obtained for different individuals and different muscles were evaluated with the aid of six two-way analyses of variance using hierarchical models. The analyses show that statistically significant differences exist between the mean values of individuals as well as of muscles. This result holds for all six parameters.

The analyses of variance also yield the standard deviation components shown in Table 2. As can be seen from the table, the most im-

Table 1 Power spectrum characteristics of the myoelectric signal for male ... controls

Muscle	α(dB) mean	α(dB) std dev	β(dB) mean	β(dB) std dev	γ(dB) mean	γ(dB) std dev
Trapezius	—6 6	2 6	16 6	2 5	25 9	4.1
Deltoideus	—5 9	3 0	16 1	1 9	24 5	4.3
Biceps brachii	—5 7	2 4	16 3	2 0	26 4	4.0
Brachioradialis	—6 0	2 6	16.2	1 7	25 0	4 4
Extensor digitorum communis	—5 8	3 1	16 2	2 0	24 7	5 4
Vastus lateralis	—5 0	2 6	16 0	1 7	25 0	3 7
Tibialis anterior	—6 3	2 6	16 3	2.3	26 4	3.3
Soleus	—4.3	2 9	16 5	2.3	26 2	3.8
Gastrocnemius	—5 5	2 9	17 3	2 7	27 3	4.2

Parameters α β and γ are ratios of activity power in a band centered at 700 Hz to activity powers in equally wide bands centered at 50 800 and 1600 Hz respectively. Parameters s f_c and Δ_{max} are slope of high frequency asymptote corner frequency and difference between low frequency and 200 Hz levels of corner fre

portant source of variation for all six parameters is to be found within the muscle i e *in the differences between values obtained for different* positions of the needle electrode *within a muscle* The next most important source of variation also for all six parameters is the differences *between muscles* It follows that the least important factor again for all six parameters—is *interindividual* variation The standard deviations of the set of parameters α β γ consistently take on their largest values for parameter γ and their smallest values for parameter β Since parameters s f_c and Δ_{max} are of different dimensions their deviations cannot immediately be compared It is evident however that the corner frequency f – not surprisingly has considerable variation

The fact that interindividual variations are significant implies that individuals having high parameter values for one muscle have high parameter values for other muscles also

Tables 3 8 show matrices of the differences between the six parameter values respectively of the nine different muscles By means of the T method for comparisons of contrasts (Brownlee 1960) it is found that pair differences having magnitude exceeding 0 5 for α 0 4 for β 0 8 for γ 0 6 for s 16 for f and 0 9 for Δ_{max} are significant These differences are printed in italics

contractions of nine muscles of the right arm and leg in 50 uninjured male 20 to 50 years

s (dB/octave) mean	std dev	f_s (Hz) mean	std dev	A_{max} (dB) mean	std dev	$r_{\alpha\beta}$ (50/800)	$r_{\alpha\gamma}$ (50/1600)	$r_{\beta\gamma}$ (800/1600)
—9 2	3 0	129	77	8 0	3 9	0 10	—0 07	0 73
—8 4	3 1	114	75	7 8	5 5	—0 01	—0 02	0 70
—10.2	3 1	166	82	6 9	3 9	—0 05	—0 08	0 68
—8 7	3 0	126	75	7 4	4 1	0 05	—0 10	0 69
—8 5	3 3	119	82	7 4	3 4	—0 12	—0 20	0 72
—9 0	2 8	115	83	6 4	3 2	0 05	—0 09	0 69
—10 2	2 5	159	70	8 0	5 7	0 15	—0 02	0 76
—9 7	2 6	165	75	5 8	3 0	—0 06	—0 17	0 75
—10 0	2 7	151	80	7 0	3 [illegible]	0 02	—0 07	0 78

quency model, respectively Symbol $r_{\alpha\beta}$ denotes coefficient of correlation between α and β etc Measurements were carried out at eight different needle electrode positions in each muscle

Several striking features are found in Tables 3–8 Comparison of the number of significant differences for the various parameters shows that except for m gastrocnemius the values of the ratio β are particularly uniform It is also seen that in a majority of cases significant γ differences are accompanied by significant differences in $s = \beta - \gamma$ occasionally in conjunction with significant differences in one or several of the other parameters also Significant γ differences accompanied by significant β differences *but not* by significant s differences are quite exceptional (m gastrocnemius vs mm biceps brachii

Table 2 Partition of total standard deviations (σ of α β γ s f_s and A_{max} in contributions due to intramuscular variations (σ_1) intermuscular variations (σ_2) and interindividual variations (σ_3) nine right side muscles of 50 uninjured controls

Standard deviation component	α(dB)	β(dB)	γ(dB)	s(dB/octave)	f (Hz)	A_{max} (dB)
σ_1	2 4	1 7	3 5	2 6	71	3 9
σ_2	1 4	1 1	1 8	1 [illegible]	32	1 3
σ_3	0 8	0 7	1.3	0 9	21	0 8
σ	[illegible]9	2 2	4 2	3 0	81	4 2

Table 3. *Differences in dB between average α values of nine muscles (limit of significance = 0.5; significant differences are printed in italics)*

	Mean	Trapezius	Deltoideus	Biceps brachii	Brachioradialis	Extensor digitorum communis	Vastus lateralis	Tibialis anterior	Soleus	Gastrocnemius
Mean		−6.6	−5.9	−5.7	−6.0	−5.9	−5.0	−6.3	−4.3	−5.5
Trapezius	−6.6	—								
Deltoideus	−5.9	*−0.7*								
Biceps brachii	−5.7	*−0.9*	−0.2	—						
Brachioradialis	−6.0	*−0.6*	0.1	0.3	—					
Extensor digitormu communis	−5.8	*−0.8*	−0.1	0.1	−0.2	—				
Vastus lateralis	−5.0	*−1.6*	−0.9	−0.7	*−1.0*	−0.8	—			
Tibialis anterior	−6.3	−0.3	0.4	*0.6*	0.3	0.5	*−1.3*	—		
Soleus	−4.3	*−2.3*	*−1.6*	*−1.4*	*−1.7*	*−1.5*	*−0.7*	*−2.0*	—	
Gastrocnemius	−5.5	*−1.1*	−0.4	−0.2	−0.5	0.3	−0.5	*0.8*	*1.2*	—

Table 4. *Differences in dB between average β values of muscles (limit of significance = 0.4; significant differences are printed in italics)*

	Mean	Trapezius	Deltoideus	Biceps brachii	Brachioradialis	Extensor digitorum communis	Vastus lateralis	Tibialis anterior	Soleus	Gastrocnemius
Mean		16.6	16.1	16.3	16.2	16.0	16.3	16.5	17.3	
Trapezius	16.6	—								
Deltoideus	16.1	*0.5*	—							
Biceps brachii	16.3	0.3	−0.2	—						
Brachioradialis	16.2	0.4	−0.1	0.1	—					
Extensor digitormu communis	16.2	0.4	0.1	0.1	0.0					
Vastus lateralis	16.0	*0.6*	0.1	0.3	0.2	0.2	—			
Tibialis anterior	16.3	0.3	0.2	0.0	0.1	−0.1	−0.3	—		
Soleus	16.5	0.1	0.4	−0.2	−0.3	0.3	*0.5*	0.2		
Gastrocnemius	17.3	*0.7*	*1.2*	*1.0*	*−1.1*	*1.1*	*1.3*	*1.0*	*−0.8*	

Table 5 Differences in dB between average γ values of nine muscles (limit of significance = 0.8 significant differences are printed in italics)

	Mean	Trapezius	*Deltoideus*	Biceps brachii	Brachioradialis	Extensor digitorum communis	Vastus lateralis	Tibialis anterior	Soleus	Gastrocnemius
Mean		25.9	24.5	26.4	25.0	24.7	25.0	26.4	26.2	27.3
Trapezius	25.9	—								
Deltoideus	24.5	*1.4*	—							
Biceps brachii	26.4	—0.5	*—1.9*	—						
Brachioradialis	25.0	*0.9*	—0.5	*1.4*	—					
Extensor digitormu communis	24.7	*1.2*	—0.2	*1.7*	0.3	—				
Vastus lateralis	25.0	*0.9*	—0.5	*1.4*	*0*	—0.3	—			
Tibialis anterior	26.4	—0.5	*—1.9*	0	*—1.4*	*—1.7*	*—1.4*	—		
Soleus	26.2	—0.3	*—1.7*	0.2	*—1.2*	*—1.5*	*—1.2*	0.2	—	
Gastrocnemius	27.3	*—1.4*	*—2.8*	*—0.9*	*—2.3*	*—2.6*	*—2.3*	*—0.9*	*—1.1*	—

Table 6 Differences in dB/octave between average s values of nine muscles (limit of significance = 0.6 significant differences are printed in italics)

	Mean	Trapezius	Deltoideus	Biceps brachii	*Brachioradialis*	Extensor digitorum communis	Vastus lateralis	Tibialis anterior	Soleus	Gastrocnemius
Mean		—9.2	—8.4	—10.2	—8.7	—8.5	—9.0	—10.2	—9.7	—10.0
Trapezius	—9.2	—								
Deltoideus	—8.4	*—0.8*	—							
Biceps brachii	—10.2	*1.0*	*1.8*	—						
Brachioradialis	—8.7	—0.5	0.3	*—1.5*	—					
Extensor digitormu communis	—8.5	*—0.7*	*0.1*	—1.7	—0.2	—				
Vastus lateralis	—9.0	—0.2	0.6	*—1.2*	0.3	0.5	—			
Tibialis anterior	—10.2	*1.0*	*1.8*	0	*1.5*	*1.7*	*1.2*	—		
Soleus	—9.7	0.5	*1.3*	—0.5	*1.0*	*1.2*	*0.7*	—0.5	—	
Gastrocnemius	—10.0	*0.8*	*1.6*	—0.2	*1.3*	*1.5*	*1.0*	—0.2	0.3	—

Table 7 Differences in Hz between average f_s values of nine muscles (limit of significance = 16 significant differences are printed in italics)

Mean	Mean	Trapezius	Deltoideus	Biceps brachii	Brachioradialis	Extensor digitorum communis	Vastus lateralis	Tibialis anterior	Soleus	Gastrocnemius
		129	114	166	126	119	115	159	165	151
Trapezius	129	—								
Deltoideus	114	15	—							
Biceps brachii	166	*—37*	*—52*	—						
Brachioradialis	126	— 3	—12	*40*	—					
Extensor digitormu communis	119	10	— 5	*47*	7	—				
Vastus lateralis	115	14	— 1	*51*	11	4	—			
Tibialis anterior	159	*—30*	*—45*	7	*—33*	*—40*	*—44*	—		
Soleus	165	*—36*	*—51*	1	*—39*	*—46*	*—50*	— 6	—	
Gastrocnemius	151	*—22*	*—37*	15	*—25*	*—32*	*—36*	8	14	—

Table 8 Differences in dB between average A_{max} values of nine muscles (limit of significance = 0.9 significant differences are printed in italics)

Mean	Mean	Trapezius	Deltoideus	Biceps brachii	Brachioradialis	Extensor digitorum communis	Vastus lateralis	Tibialis anterior	Soleus	Gastrocnemius
		8.0	7.8	6.9	7.4	7.4	6.4	8.0	5.8	7.0
Trapezius	8.0									
Deltoideus	7.8	0.2	—							
Biceps brachii	6.9	*1.1*	0.9	—						
Brachioradialis	7.4	0.6	0.4	0.5	—					
Extensor digitormu communis	7.4	0.6	0.4	0.5	0	—				
Vastus lateralis	6.4	*1.6*	*1.4*	0.5	*1.0*	*1.0*				
Tibialis anterior	8.0	0	0.2	*1.1*	0.6	−0.6	*−1.6*			
Soleus	5.8	*2.2*	*2.0*	*1.1*	*1.6*	*1.6*	0.6	*2.2*		
Gastrocnemius	7.0	*1.0*	0.8	0.1	0.4	0.4	−0.6	*1.0*	*1.2*	

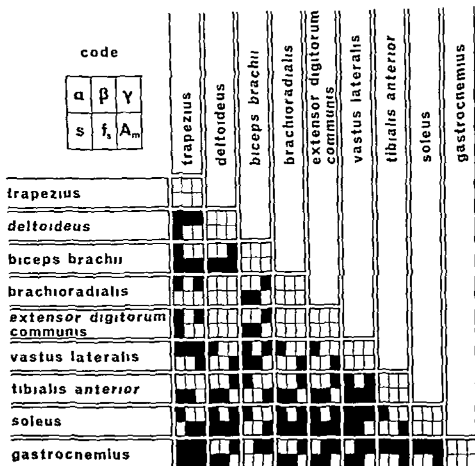


Figure 4 Significant differences (= filled rectangels) between pairs of right side muscles with respect to α β γ s f and A_{max}

tibialis anterior and soleus and m vastus lateralis vs m trapezius)

It should also be noted that the α differences of m trapezius are significant in all cases but one (higher low frequency content for m trapezius) and that the A_{max} differences of m soleus are significant also in all cases but one (lower low frequency content for m soleus in agreement with the previous statement concerning α)

A simultaneous presentation of all significant differences between pairs of muscles with respect to the six spectrum parameters is given in Figure 4

The only pairs displaying no statistically significant spectrum param

Table 7 Differences in Hz between average f_s values of nine muscles (limit of significance = 16 significant differences are printed in italics)

	Mean	Trapezius	Deltoideus	Biceps brachii	Brachioradialis	Extens ordigitorum communis	Vastus lateralis	Tibialis anterior	Soleus	Gastrocnemius
Mean		129	114	166	126	119	115	159	165	151
Trapezius	129	—								
Deltoideus	114	15	—							
Biceps brachii	166	*—37*	*—52*	—						
Brachioradialis	126	— 3	—12	*40*	—					
Extensor digitormu communis	119	10	— 5	*47*	7	—				
Vastus lateralis	115	14	— 1	*51*	11	4	—			
Tibialis anterior	159	*—30*	*—45*	7	*—33*	*—40*	*—44*	—		
Soleus	165	*—36*	*—51*	1	*—39*	*—46*	*—50*	— 6	—	
Gastrocnemius	151	*—22*	*—37*	15	*—25*	*—32*	*—36*	*8*	*14*	—

Table 8 Differences in dB between average A_{max} values of nine muscles (limit of significance = 0.9 significant differences are printed in italics)

	Mean	Trapezius	Deltoideus	Biceps brachii	Brachioradialis	Extens ordigitorum communis	Vastus lateralis	Tibialis anterior	Soleus	Gastrocnemius
Mean		8.0	7.8	6.9	7.4	7.4	6.4	8.0	5.8	7.0
Trapezius	8.0	—								
Deltoideus	7.8	0.2	—							
Biceps brachii	6.9	*1.1*	0.9	—						
Brachioradialis	7.4	0.6	0.4	—0.5	—					
Extensor digitormu communis	7.4	0.6	0.4	—0.5	0	—				
Vastus lateralis	6.4	*1.6*	*1.4*	0.5	*1.0*	*1.0*	—			
Tibialis anterior	8.0	0	—0.2	*—1.1*	—0.6	—0.6	*—1.6*	—		
Soleus	5.8	*2.2*	*2.0*	*1.1*	*1.6*	*1.6*	*0.6*	*2.2*	—	
Gastrocnemius	7.0	*1.0*	0.8	—0.1	0.4	0.4	—0.6	*1.0*	*—1.2*	—

Table 3 Power spectrum characteristics of the myoelectric signal for moderate contractions of the left side mm biceps brachii brachioradialis and extensor digitorum communis in 25 uninjured male controls aged 20 to 50 years

Muscle	α(dB) mean	α(dB) std dev	β(dB) mean	β(dB) std dev	γ(dB) mean	γ(dB) std dev	s(dB/octave) mean	s(dB/octave) std dev	f_s (Hz) mean	f_s (Hz) std dev	A_{max} (dB) mean	A_{max} (dB) std dev
Biceps brachii	—6 8	1 9	17 6	1 5	27 9	3 5	—10 3	2 6	146	61	7 6	2 5
Brachioradialis	—5 7	2 1	17 0	1 1	25 8	3 1	—8 8	2 6	124	65	7 0	5 5
Extensor digitorum communis	—5 8	2 9	16 6	1 2	24 4	3 4	—7 8	2 8	99	6[illegible]	7 3	2 8

Measurements were carried out at eight different needle electrode positions in each muscle

Table 10 Partition of total standard deviations (σ of a, β γ s f_s and A_{max} in contributions due to intramuscular variations (σ_1) intermuscular variations (σ_2) and interindividual variations (σ_3) three left side muscles of 25 uninjured controls

Standard deviation component	a(dB)	β(dB)	γ(dB)	s(dB/octave)	f_s (Hz)	A_{max} (dB)
σ_1	2 0	1.2	3 0	2 5	60	3 7
σ	1 0	0 6	2 1	1 5	31	0.9
σ_3	0 8	0 4	1 0	0 7	15	0 8
σ	2 4	1 4	3 8	3 0	69	3 9

Comparison between Right and Left Side Muscles

1 *Mm Biceps Brachii, Brachioradialis and Extensor Digitorum Communis*

The left side mean values and standard deviations of a β γ s, f_s and A_{max} for these three muscles are shown in Table 9

Analyses of variance were carried out for each of the six spectrum parameters with the result that statistically significant differences

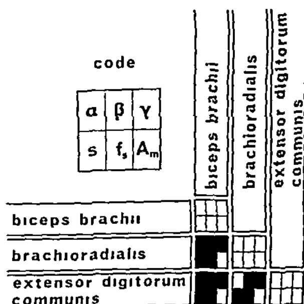


Figure 5 Significant differences (= filled rectangels) between pairs of left side muscles with respect to a β γ s f_s and A_{max}

exist between the mean values of individuals as well as of muscles This result holds for all six parameters

The standard deviation components yielded by the analyses of variance are shown in Table 10 As for the right side muscles intra muscular variation is most important intermuscular variation is next most important and interindividual variation is least important Also as for the right side the standard deviations of the set of parameters α β γ consistently take on their largest values for γ and their smallest values for β

A simultaneous presentation of all significant differences between pairs of muscles with respect to the six spectrum parameters is given in Figure 5 Comparison of Figures 4 and 5 shows that the number of statistically significant intermuscular differences is larger for the left side than for the right side

Comparison of the left side values in Table 9 with the corresponding right side values in Table 1 shows the following differences to be statistically significant α β γ f_s and A_{max} of m biceps brachii β γ and A_{max} of m brachioradialis and β s and f_s of m extensor digitorum communis

2 *Mm Interosseus Dorsalis I Manus and Extensor Digitorum Brevis*

The left side and right side mean values and standard deviations of α β γ s f and A_{max} for each of these two muscles are shown in Table 11

Differences between individuals and between sides were evaluated by means of two way hierachical analyses of variance with the result that differences between individuals are statistically significant for both muscles whereas statistically significant differences between the right and the left side appear in the α γ s, f_s and A_{max} values only of m interosseus dorsalis I manus and in the β and γ values only of m extensor digitorum brevis The analyses also yield the standard deviation components shown in Table 12

The table shows that for these two muscles also the most important source of variation for all six parameters is to be found within the muscle (cf Table 2) Interindividual variations are more important than interside variations for all parameters of both muscles except for the s and f values of m interosseus dorsalis I manus

Comparison of the right side α β γ s f_s and A_{max} values in Table 11 with the corresponding values in Table 1 shows generally speaking

Table 11 Power spectrum characteristics of the myoelectric signal for modera m extensor digitorum brevis in

Muscle	Side	α(dB) mean	α(dB) std dev	β(dB) mean	β(dB) std dev	γ(dB) mean	γ(dB) std dev
Interosseus dorsalis I	right	—3 8	3 2	16 3	2 0	27 2	3 9
manus	left	—4 0	3 3	16 6	2 5	26 9	4 6
Extensor digitorum	right	—3 1	1 5	16 6	2 6	27 1	4 6
brevis	left	—2 7	3 0	17 7	3 2	28 7	4.8

Measurements were carried out at four different needle electrode positions in each muscle

markedly low α and A_{max} (low frequency parameters) markedly high γ s and f_s (high frequency parameters) and average β Apart from a moderate increase in magnitude the right side coefficients of correlation in Table 11 display the same characteristics as those of the nine right side muscles in Table 1

It is interesting to note that statistically significant parameter differences between the left and right sides of mm interosseus dorsalis I manus and extensor digitorum brevis take place in the same directions as the corresponding statistically significant left to right side differences of mm biceps brachii brachioradialis and extensor digitorum communis This effect is particularly pronounced for parameter β

Influence of Muscle Temperature

Muscle temperature of the 50 uninjured controls measured in the right side long head of m biceps brachii in the vicinity of point 1 varied between 35 0 and 37 5° C the mean value was 36 4 C Inspection of scatter diagrams revealed no discernible temperature dependence of the α β γ s f_s or A_{max} values It can be noted that neither does the duration of low level contraction action potentials vary significantly over this limited temperature range (see Buchthal et al 1954)

Temperature differences recorded for 20 uninjured controls between points 1 and 8 of the right side m biceps brachii and between point 1 of the right side and point 1 of the left side m biceps brachii did not in any case exceed 0 1 C Thus temperature influence cannot explain the power spectrum differences between points 1 and 8 or between the left and right sides

tractions of the right and left side m interosseus dorsalis I manus and njured male controls aged 20 to 50 years

s(dB/octave) mean	std dev	f (Hz) mean	std dev	A_{max} (dB) mean	std dev	$r_{\alpha\beta}$ (50/800)	$r_{\alpha\gamma}$ (50/1600)	$r_{\beta\gamma}$ (800/1600)
—10 9	2 9	202	84	5 2	2 9	—0 04	—0 13	0 69
—10.3	3 0	177	79	5 6	2 6	—0 21	—0 35	0 79
—10 5	3 0	190	82	5 0	3 3	—0 18	—0 20	0 81
—11 1	2 9	199	87	4 6	2 5	—0 16	—0 16	0 81

Amputees

The mean values and standard deviations of α β γ s f and A_{max} for muscles of amputees with normal EMG are shown in Table 13 Values obtained for muscles of amputees with neurogenic EMG are shown in Table 14 The tables include the spectrum parameters of those muscle groups only which contain at least three muscles (corresponding to at least 12 myoelectric signals)

Comparison between Muscles Yielding Normal and Neurogenic EMG Respectively

Due to limited group size differences between the spectrum parameters of signals from muscles yielding normal and neurogenic EMG

Table 12 Partition of total standard deviations (σ) of α β γ s f and A_{max} for the two muscles in contributions due to intramuscular variations (σ_1) interside variations (σ_2) and interindividual variations (σ_3) 50 uninjured controls

Muscle	Standard deviation component	α(dB)	β(dB)	γ(dB)	s(dB/octave)	f_s(Hz)	A_{max} (dB)
Interosseus dorsalis I manus	σ	2 6	2 0	3 9	2 8	73	2 3
	σ	1 4	—	1 3	1.3	33	1 0
	σ_3	1 7	1 1	1 4	0 7	31	1 4
	σ	3 4	2 3	4 4	3 1	86	2 9
Extensor digitorum brevis	σ_1	2 8	2 3	4 1	2 8	78	2 7
	σ_2	—	1 1	1 4	—	—	—
	σ_3	1 6	1 [illegible]	2 3	1 0	29	1 2
	σ	3 2	4 1	4 9	3 0	83	2 9

Table 13 Power spectrum characteristics of normal myoelectric signals fo

Above/below elbow amputation	Muscle	Side	Number of patients	α(dB) mean	α(dB) std dev
Above elbow	trapezius	right	3	—6 4	2 7
	deltoideus	left	4	—3 3	3 3
	biceps brachii	right	9	—4 9	3 [illegible]
		left	11	—4 9	3 7
Below elbow	brachioradialis	right	7	—3 0	4 3
		left	12	—3 0	2 8
	stump extensor	right	6	—4 5	3 6
		left	8	—1 9	3 6
	stump flexor	right	6	—3 0	3 8
		left	9	—4 7	3 7

Measurements were carried out at four different needle electrode positions in each muscle

could only be analyzed for the right and the left side, respectively, of the stump extensor muscles and for the right side of the stump flexor muscles Comparison of the corresponding spectrum parameters of these muscles shown in Tables 13 and 14 reveals statistically significant differences for all parameters except f_s of the right side flexor muscles In view of this result further comparisons within the group of amputees as well as between this group and the group of controls were performed for signals classified as normal only (with one exception)

Table 14 Power spectrum characteristics of neurogenic myoelectric signals for ...ng to

Muscle	Side	Number of patients	α(dB) mean	α(dB) std dev	β(dB) mean	β(dB) std dev
Stump extensor	right	3	0 1	3 5	16 9	1 7
	left	3	—8 7	4 0	20 6	6 0
Stump flexor	right	4	—3 9	2 1	21 0	4 6

Measurements were carried out at four different needle electrode positions in each muscle

moderate contractions of ten muscles of male amputees aged 20 to ‿0 years

β(dB)		γ(dB)		s(dB/octave)		f_s(Hz)		A_{max} (dB)	
mean	std dev	mean	std dev	mean	std dev	mean	std dev	mean	std dev
16 4	3 6	27 6	5 3	—11 2	2 2	158	76	12 4	14 6
17 6	2 0	28 4	5 3	—10.8	3 9	184	100	5 0	2 4
15 4	2 1	23 3	3 3	—7 9	2 5	114	64	8 6	9 8
16 4	2 1	25 9	4 1	—9 5	3 0	143	80	7 7	7 3
15 8	2 2	24 6	5 3	—8 8	3 6	144	96	7 3	10 0
16.3	2 4	25 9	5 0	—9 6	3 6	169	94	4 9	0 9
16 0	1 0	26 0	3 2	—10 0	2 9	167	64	6 3	3 0
15 7	1 7	25 1	3 4	—9 4	3 0	248	24	5 6	1 6
16 4	2 4	26 3	4 2	—9 9	3 3	171	83	3 8	3 9
15 9	2 4	26 8	2 9	—10 9	2 9	204	81	6 0	3 5

Comparison between Muscles Yielding Normal EMG

Differences between the six parameter values obtained for different individuals and different muscles having normal EMG were evaluated with the aid of analyses of variance using hierarchical models These investigations were carried out for mm biceps brachii and brachioradialis and the stump extensor muscle of below elbow amputees Right side muscles (for amputees) and left side muscles (eight amputees) were analyzed separately

The analyses show statistically significant differences between the mean values of muscles for all parameters except A_{max} of the left

moderate contractions of three muscles of male below elbow amputees aged 0 years

γ(dB)		s(dB/octave)		f_s(Hz)		A_{max} (dB)	
mean	dev std	mean	dev std	mean	dev std	mean	dev std
28 6	3 8	—11 7	2 4	243	56	2 9	1 3
31 6	3.8	—11 0	3 4	157	103	9 6	4 9
32 8	3 9	—11 8	2 0	178	90	6 0	2 4

Table 15 Partition of total standard deviations (σ) of α β γ s f_s and A_{max} in contributions due to intramuscular variations (σ_1) intermuscular variations (σ_2) and interindividual variations (σ_3) four right side amputees and eight left side amputees

Muscles	Standard deviation component	α(dB)	β(dB)	γ(dB)	s(dB/ octave)	f_s(Hz)	A_{max} (dB)
Right side							
mm biceps	σ_1	1 7	1 2	3 7	3 0	71	6 7
brachii							
brachioradialis	σ	3 9	1 0	3 4	2 5	62	5 2
and							
stump extensor	σ_3	2 0	1 1	—	—	—	2 [illegible]
muscle	σ	4 7	1 9	5 1	3 9	94	8 7
Left side							
mm biceps	σ_1	2 3	1 5	2 8	2 1	61	3 7
brachii							
brachioradialis	σ_2	3 0	1 2	1 7	1 2	53	—
and							
stump extensor	σ_3	0 9	0 7	2 9	2 2	59	—
muscle	σ	3 9	2 1	4 3	3 3	100	3 7

side Differences between individuals are statistically significant for α β and A_{max} of the right side and for all parameters except A_{max} of the left side The standard deviation components obtained from the analyses of variance are shown in Table 15

Comparison between Right and Left Side Muscles Yielding Normal EMG

Comparison of the right and left side parameter values in Table 13 shows all differences to be statistically significant except the following α and A_{max} of m biceps brachii α of m brachioradialis and β and γ of the stump flexor muscle Parameter values of the right side mm biceps brachii and brachioradialis and of the right stump flexor muscle tend to be lower than those of the corresponding left side muscles For the stump extensor muscle the opposite relation was found

Comparison between Muscles of Amputees Yielding Normal EMG and Muscles of Uninjured Controls

Statistically significant differences between the parameter values obtained for muscles of amputees yielding normal EMG and the corresponding values for uninjured controls are shown in Table 16. It is interesting to note that whenever statistically significant differences occur for right side as well as left side muscles the deviations take place in the same direction. It is also interesting to note that—without exception—the low frequency content of the amputee muscles as measured by α is low. This agrees with the also consistently low β values (although here three of the six deviations are not large enough to be statistically significant).

As might be expected with regard to etiology differences of the amputations, the deviation components listed in Table 15 differ—in absolute as well as relative magnitude—from those obtained for uninjured controls (Tables 2 and 10).

Simultaneous presentations of all significant differences between pairs of muscles with respect to the six spectrum parameters are given in Figures 6 and 7.

Comparison between Muscles of Amputees Yielding Neurogenic EMG and Muscles of Uninjured Controls

The parameter values of amputee muscles yielding neurogenic EMG could be compared to the corresponding values of uninjured controls

Table 16. Statistically significant differences between parameters of normal EMG amputee muscles and uninjured control muscles. Positive values imply that amputee parameters are larger, negative values that they are smaller than control parameters (note that all average α and s values concerned are negative).

	Muscle	α(dB)	β(dB)	γ(dB)	s(dB/octave)	f_s(Hz)	λ_{max} (dB)
	trapezius	—	—	—	−2.0	—	4.4
Right side	biceps brachii	0.8	−0.9	−3.1	2.3	−52	1.7
	brachioradialis	3.0	—	—	—	—	—
	stump extensor	1.3	—	—	−1.5	48	−1.1
Left side	biceps brachii	1.9	−1.2	−2.0	0.8	—	—
	brachioradialis	2.7	−0.7	—	−0.8	45	−2.1
	stump extensor	3.9	−0.9	—	−1.6	149	−1.7

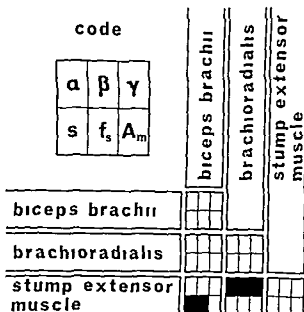


Figure 6 *Significant differences (= filled rectangels) between pairs of right side amputee muscles having normal EMG with respect to α β γ s f_s and A_{max}*

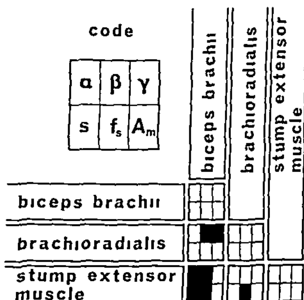


Figure 7 *Significant differences (= filled rectangles) between pairs of left side amputee muscles having normal EMG with respect to α, β γ s f_s and A_{max}*

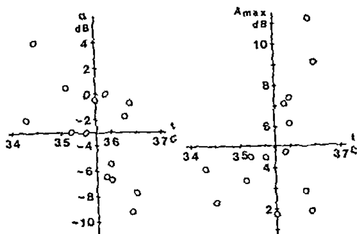


Figure 8 Scatter diagrams of parameters α and A_{max} vs temperature t

for the right and left side stump extensor muscles only For these two two muscles all parameters except β of the right muscle show statistically significant deviations

Influence of Muscle Temperature

Muscle temperature was measured in the stump extensor muscle of the 14 below elbow amputees having normal EMG for that muscle The temperature varied between 34 3 and 36 5 C the mean value was 35 7 C Inspection of scatter diagrams revealed *no* discernible temperature dependence of β, f_s or f_z As shown in Figure 8 parameters α and A_{max} are evenly distributed for temperatures above average (35 7 C) For lower temperatures however no low α or high A_{max} values were recorded This implication of low frequency content decreasing with temperature is particularly interesting in view of the increased percentage of polyphasic potentials at lower temperatures (reported by Buchthal et al 1954) It should be noted however that increased action potential duration has also been reported for lower muscle temperature (Bentsen 1945 Buchthal & Pinelli 1952)

DISCUSSION

The number of muscles included in the present investigation may seem astonishingly high In view of the urgent need of prosthesis control sites however an even more extensive set of muscles had been desi-

rable On the other hand discomfort and pain caused by needle electrode insertions have limited the number of muscles investigated This is of course particularly pronounced in the case of amputees and is the reason why the groups of amputee muscles vary in size

The present analysis of myoelectric signals yields information on the shape of the power spectrum This way of describing the signal properties is particularly useful in prosthesis design work aimed at finding optimum preprocessing filters The present investigation concentrates on the problems of intramuscular, intermuscular and interindividual variations of the shape of the power spectrum at a constant level of moderate contraction yielding signals well above the background noise in the frequency range studied The further problems of power spectrum variations with muscle load which require additional extensive investigations will be treated separately

The power spectrum frequency range of greatest interest in prosthesis control has been stated by various authors to be the interval between 100 or 300 and 1000 Hz (Battye et al 1955 Horn 1963 Hirsch et al 1964 see also Kaiser et al 1968) The low frequency limit of about 100 Hz is determined partly by the risk of mains interference partly by the relatively large erratic fluctuations encountered at lower frequencies The high frequency limit is determined by power spectrum roll off which causes the signal to noise ratio to deteriorate if frequencies much above 1000 Hz are included Investigations of this power spectrum should thus cover a frequency range of about 50 to 2000 Hz In order to achieve a reasonable data reduction we have taken measurements at four points—corresponding to the average powers in octaves centered at 50 200 800 and 1600 Hz—within this range Further data reduction to three recorded points per electrode position is obtained by performing all measurements at essentially the same level of contraction

The measured values α β and γ can of course be converted into high frequency asymptote slope and corner frequency—standard concepts of filter and circuit theory—in several ways The fundamental method used in the present paper based on the cubic approximation in Eq (1) has the advantage of being applicable in most cases When the third power curve did not display a finite maximum which happened for about two per cent of the spectra a parabola connecting the 50 200 and 800 Hz points was used instead The condition that the interconnecting curve has exactly the same slope as the high frequency asymptote at 800 Hz was thus waived for these spectra This

procedure does not, of course, influence the α, β, γ or s values, and provides f_s and A_{max} values well within the range of variation of the other spectra. For five individual spectra (of a total of more than 5000) the 50, 200 and 800 Hz points were situated on a straight line, excluding the possibility of assigning maxima to the spectra. [illegible] of the random measurement-error component, and in order to [illegible] the irregularity of the spectra concerned, the α value [illegible] cases—typically about −11 dB—was increased by one dB. The [illegible] of the extremely low α values (high low frequency content as [illegible] in the 50 Hz band) is not clear; the possibility of [illegible], e.g. mains interference, cannot, of course, be excluded.

Skeleton muscles in higher vertebrates have been divided into two types, red and white. The red muscles perform sustained contractions and the white perform rapid phasic movements (Denny-Brown, 1929; Creed et al., 1932; Kruger, 1952). The red and white muscle fibres constitute a complex mixture within the same muscle of the vertebrates.

Red and white muscles have previously been studied from the functional point of view, physiologically characterized by long and short contraction times, respectively. At that time it was justifiable to refer to slow and rapid muscles, as it was believed that all muscle fibres in a slow muscle performed sustained contractions, even though all fibres were not red.

The existence of different mononeurons with different functions, so called phasic and tonic motoneurons, was later demonstrated on cat (Granit et al., 1956; Eccles et al., 1958). In the tonic motoneurons Eccles et al. (1958) found a long after-hyperpolarization potential causing a reduced level of excitation. These neurons thus fire at lower frequencies than the phasic motoneurons. The tonic neurons also have thinner fibres and transmit the impulses at lower velocities. The type of motoneuron activating the muscle was considered decisive for the phasic or tonic action of the muscle.

By means of histochemical methods it has recently been proved on rat that with respect to function there are different muscle fibres (Kugelberg & Edstrom, 1968; Edström & Kugelberg, 1968). These authors showed that the phasic muscle fibres, mainly supplied with aerobe energy, were less easily fatigued. The tests were carried out by stimulating the rat muscle to such an extent that the circulation was not seriously affected. It was believed that the phasic muscle fibres were prevented from being unneccessarily activated in ordinary muscle

contractions by innervation of special phasic motoneurons A striking relation between the difference in fatiguability and the histochemically verified type of muscle was demonstrated in stimulating single motor units (Edstrom & Kugelberg 1968) It was found that individual motor units were largely uniform as regards muscle fibre type

Tokizane & Shimazu (1964) proved that human muscle also contains phasic and tonic muscle fibres These functionally different motor units are both present in all muscles studied by these authors but with intermuscular variations between for instance facial muscles Furthermore phasic units were morphologically more spread than the tonic units which were mainly situated in the central part of the muscle

Kugelberg & Edstrom (1968) showed that stimulation producing fused contraction in rat muscle caused a considerable obstruction of the blood flow Simultaneously a pronounced muscular fatigue rapidly developed which was considered to be due to a failure of the neuromuscular transmission acting as a protection of the muscle fibre At a lower frequency of stimulation the developing muscle fatigue depended on contractile elements being affected

Dynamic changes of the myoelectric power spectrum during fatiguing isometric muscle contraction were investigated by Kadefors et al (1967 1968) The authors discussed the possibility that the decline of signal activity in the high frequency range could be due to a drop out of rapid motor units These motor units probably correspond to the phasic rapidly fatiguable units The relation between muscular blood flow and power spectrum in sustained maximal contraction of the human muscle has recently been studied by Kadefors et al (1969)

Although several mechanisms may conceivably be responsible for the differences in power spectrum shape a number of the present results appear particularly interesting in view of the existence of functionally different types of motor units Thus mm gastrocnemius and soleus which are often referred to as typical examples of muscles having fast and slow muscle contraction rates, respectively differ strikingly from other muscles The *high frequency* content (in the 800 and 1600 Hz ranges) of the m gastrocnemius signal is significantly *less* than that of all the other eight muscles used for comparison and the *low-frequency* content (in the 50 Hz range) of the m soleus signal is also significantly *less* than that of all the other eight muscles Thus both muscles display extreme properties in the power spectrum domain also The relatively small low frequency content of the slow

m soleus and the relatively small high frequency content of the fast m gastrocnemius are however not remarkable (since for example short duration potential components may occur superimposed on action potentials of long durations and short duration action potentials may occur in periodical bursts)

SUMMARY

Power spectra of myoelectric signals for moderate short lasting muscle contractions were measured in 50 uninjured controls and 30 arm amputees all males and aged 20 to 50 years A method yielding the four average spectrum levels in octave bands centered at 50 200 800 and 1600 Hz was used

In the control group 11 right side and 5 left side limb muscles were studied Statistically significant intramuscular (most important) intermuscular (next most important) and interindividual (least important) level differences were found Differences between right and left sides were also significant

In the arm amputee group spectrum differences were demonstrated between muscles having normal and neurogenic EMG respectively As for the control group intramuscular intermuscular interside and interindividual differences were found for muscles having normal EMG

Statistically significant power spectrum differences were found between control muscles and amputee muscles This result was obtained for the normal EMG as well as the neurogenic-EMG groups of amputee muscles

No pronounced power spectrum temperature dependence was observed neither for control nor amputee muscles

The four spectrum levels were also transformed into high frequency asymptote slope and corner frequency of a piecewise linear spectrum model These transformed parameters displayed essentially the same statistically significant differences as the levels themselves

The results are discussed with regard to optimal signal processing in prosthesis control and with regard to the existence of functionally different types of motor units

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TRAUMATIC PANNUS

I Macroscopical and Microscopical Changes after Experimental Reconstruction of the Joint Surface

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Pannus formation is a reply to changes and defects which have developed during various pathological processes in joints The pannus is described as a fragile cellular and well vascularized tissue that grows from the synovial lining or from the opened vascular spaces of the subchondral bone Later it loses its original cellularity and vascularisation and changes into a fibrous tissue which can undergo further differentiation depending on the functional load of the damaged joint According to the tissue activity related to the articular surface one distinguishes a chondrolytic ossifying ankylosing fibrositing pannus The development of the pannus can be caused by a series of different factors

1 Traumatic lesion of the articular cartilage If the defect of the cartilage is so deep that it perforates the subchondral plate a vascular and cellular tissue grows into the defect from the subchondral vascular spaces (*Carlson 1957 Landells 1957 Banks 1966 Akeson 1969 Campbell 1969*)

2 Traumatic damage of intraarticular structures such as menisci and cruciate ligaments In such a case the granulation tissue develops in the area of the lesion and overgrows the nearest articular cartilage (*Helfet 1959*)

3 Ischaemia affecting the joint During such changes both kinds of pannus develop the intraarticular and the medullary pannus The first one is created by proliferation from the synovial membrane or from intraarticular structures and covers the surface of the joint cartilage The second kind develops in the intramedullary spaces penetrates

through the articular cartilage and later becomes connected with the intraarticular pannus (Rutishauser & Taillard 1966)

4 Immobilization of the joint Irreversible damage of the cartilage results from prolonged therapeutical or experimental immobilization of joints The cartilage becomes covered by a connective tissue growing out either from the capsule or from the medullary spaces after the perforation of the cartilage (Evans & Eggers 1960, Akeson 1961 Hall 1964)

5 Continuous extensive pressure on the joint surface destroys articular cartilage. In such a case the defect may be repaired by the deeply situated chondrocytes which have escaped death or by granulation tissue growing out from the subchondral marrow spaces (Trias 1961 Thompson & Basset 1970)

6 Articular cartilage is damaged not only from excessive pressure but also from absence of weight bearing The relief of contact in joints results in early subchondral vessel invasion of the cartilage matrix and loss of the zone of calcified cartilage (Hall 1969)

7 Damage of the articular cartilage during degenerative processes In such cases the pannus develops mostly from the synovial lining and covers both the healthy and necrotic cartilage in those areas that are in contact with the synovial membrane (Salter & McNeil 1965 Nakoneczny 1967 Batra Charnley 1969 Mankin & Lippiello 1970)

8 Damage of a healthy articular surface by contact with the synovial lining The cause can be a lesion of the capsule a one-term or continuous overloading or a maximal excursion of the joint Cooper (1961) describes "kissing or contact hip syndrome which can manifest itself as a productive or destructive lesion of the anterior portion of the neck and margin of the head of the femur

9 Rheumatoid arthritis The inflammation of the synovial membrane is the cause of the pannus formation in rheumatoid joints This pannus which consists of an apron of vascular granulation tissue composed of proliferating fibroblasts collagen fibers numerous small blood vessels and variable numbers of inflammatory cells overgrows the articular cartilage and replaces it (Hamerman 1969)

The aim of our experiments was a detailed investigation of the pannus and changes occurring in it after transplantation of an autograft or homograft of the articular non weight bearing surface

MATERIAL AND METHODS

For our experiments 90 adult mongrel dogs were used of a mean weight of 12 kg The whole anterior portion of the distal end of the femur the osseous component of which was 6 to 8 mm thick was transplanted A homograft was placed into the right knee and into the left knee an autogenous graft taken from the other knee joint Homografts were preserved for 7 to 14 days in paraffin oil at a temperature of 4 C Homografts were treated in different ways before transplantation by conservation only (Fiala et al 1965) by drilling the graft through (Fiala & Bartoš 1967) by drilling a part of homogenous cancellous bone and its replacement by the autogenous one (Fiala & Herout 1965) by washing of the cancellous bone and its impregnation with autogenous marrow (Fiala & Bartoš 1971) by washing of the cancellous bone followed by impregnation of a fibroblastic substance (Bartoš & Fiala 1971) and by X ray irradiation of the graft followed by washing and impregnation of the cancellous bone with autogenous bone marrow (Fiala & Herout 1972)

The grafts were fixed to the bed with a single wire loop Before sacrificing the blood vessels of each experimental animal were injected with a mixture of Indian ink and gelatine The grafts were removed with their beds and fixed in a 4 per cent neutral solution of formalin After decalcification in a mixture of formic and muriatic acids the preparations were imbedded into paraffin Histological sections were stained with hematoxylin and eosin Alcian blue and by Mallory's van Gieson's and Goldner's techniques The vascularization was studied in unstained sections 250 μm thick

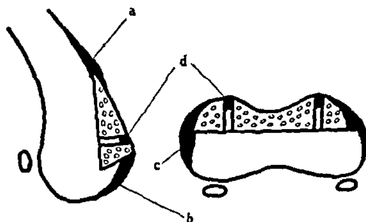


Figure 1 The distal end of the femur The graft is spotted the pannus marked in dark Pannus formation (a) at the connection between the cartilage of the graft and the periosteum of the bed (b) at the junction of the cartilage of the graft with the bed (c) at the connection of the graft basis and bed (d) in the drilled defect

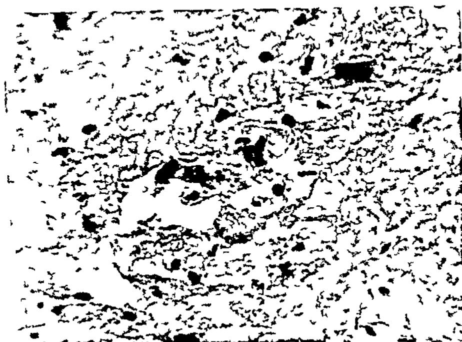


Figure 2 Pannus from the basis of the autograft 4 days after transplantation (1/67 A) The network of the fibrinous bundles among which numerous erythrocytes their remnants and dark coloured nuclei of degenerated leukocytes can be found In the middle of the picture there is a mitosis of a fibroblastoid cell Van Gieson × 400

RESULTS

In the joints opened 2 to 5 days after operation the pannus was found in all areas where the graft was in contact with the bed (Figure 1) The greater the difference between the size of the graft and the bed the larger was the amount of the pannus The pannus was of a fragile consistence and adhered only slightly to the articular cartilage Its *bright red colour* distinctly reflected against the surrounding darker tissue where after injection of the blood vessels of the cancellous bone with Indian ink the cartilage of the bed looked dark blue and the synovial membrane black Only the cartilage of the graft preserved its pinkish colouring

In the transverse thick sections blood vessels injected with Indian ink were found only in the bed and in the regions of junction of the graft The blood vessels penetrated neither into the graft itself nor into the pannus

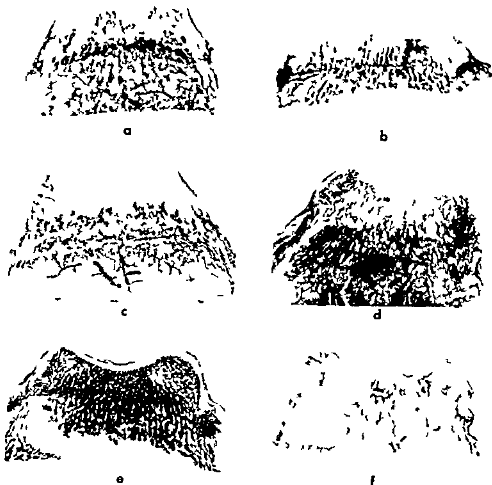


Figure 3 Histotopograms of the junction of the graft with the bed (a) Autograft 7 days after transplantation (10/6ɔ A) The connection of the graft and the bed is characterized by high vascularity Pannus on the right side of the graft is not yet vascularized on the left side the initiated vascularity can be seen (b) Autograft 9 days after transplantation (91879 A) On the right side the pannus fills in the incongruity between the graft and the bed The initiated blood vessel invasion (c) Homograft 14 days after transplantation (ɔ/67 H) The lower half of the graft is vascularized and the blood vessels penetrate the pannus approximately to the same level (d) Autograft 21 days after transplantation (7/6ɔ A) The graft is vascularized nearly in its whole thickness and the dark colour of pannus shows the great amount of blood vessels in it (e) Homograft 28 days after transplantation (91027 H) The plastic pannus on the right side of the junction of the bed and graft is formed by an island of the osteoid tissue without any orientation of its trabecullae (f) Homograft 98 days after transplantation (98098 H) The typical form of the pannus can be seen on both sides of the graft Unstained sections 00 ɔ00 µm thick blood vessels are filled with mixture of Indian ink and gelatine ×

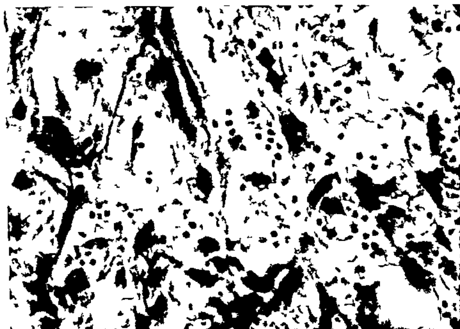


Figure 4 *Pannus from the basis of the autograft 7 days after transplantation (2/67 4) Near the penetrating blood vessels there are many fibrocytes some of which are found in mitoses The fine collagenous fibres are without a distinct orientation Van Gieson × 400*

The histological picture showed a network of fibrin bundles of various thicknesses with cellular elements between them Most of these elements were erythrocytes many of them dying off with only the cell membranes left over Polymorphonuclear leukocytes also partly de generated were marked only by pyknotic sphericles left over by their nuclei Mononuclear cells were mostly of the histiocytic type Some of the fibroblastoid cells were observed during their mitotic division (Figure 2)

From the 6th day after transplantation the marginal parts of the pannus adjacent to the periosteum were losing their original sharp bright coloured demarcation (Figure 3 a b)

In the histological pictures the original stroma of the pannus was preserved only in these areas that had not been penetrated by the blood vessels The number of erythrocytes decreased remarkably In the areas of blood vessel penetration numerous small empty spaces developed Around the vessels a rich cellular population mostly fibro



Figure 5. Pannus from the basis of the autograft 21 days after transplantation (4/67 A). On the picture is the junction of the cancellous bone of the graft with the pannus. The bundles of thick collagenous fibres running parallel with the surface pass into the trabeculae of the graft. Mallory × 100

cytes can be found. Many mitotic divisions and fine collagenous fibres without a distinct orientation were observed (Figure 4).

In the second and third week the unsharp demarcation of the pannus also began to manifest itself in the areas where it adhered to the articular cartilage of the graft (Figure 3 c, d).

In histological slides the pannus tissue started to acquire a pattern of a maturing granulation tissue. Among the cells fibrocytes prevailed. The tissue that adhered to the bone contained bundles of collagenous fibres running in parallel with the surface of the bone. Nearer to the surface the collagenous network was finer and thinner. In some spots mostly near the base of the graft rudiments of thin osseous trabecules and small marrow spaces were formed (Figure 5). Near the surface of the pannus histiocytic and fibroblastic elements were found as well as single erythrocytes.

Within the time from the 4th to the 8th week after transplantation the consistency of the pannus changed. The originally brittle and soft



Figure 6 Pannus from the basis of the autograft 2 months after transplantation (7/67 A) An island of fibrocartilage at the base of the pannus is formed Mallory × 100

tissue gradually became more consistent and it was no longer possible to separate it from the cartilage without damaging it

At this time the two main kinds of the pannus could already be distinguished the plastic one and the lytic one The plastic form developed most frequently in the areas of proximal connection of the graft and the bed On places of the original pannus deposits were formed protruding above the articular surface firmly adhering to the base and covered with a glistening white tissue The lytic kind of pannus was mostly observed at the sides of the graft as a defect penetrating more into the graft than into the bed This form of the pannus was frequently found in homografts (Figure 3 e f)

In histological slides the pattern of the pannus was that of a mature scar tissue It was formed by a network of dense bundles of collagenous fibres fibroblasts and blood vessels were very rare In numerous places fibrous cartilage (Figure 6) or young bony tissue developed

In regions where the articular cartilage was overlaid by the pannus



Figure 7 The side of the autograft 70 days after transplantation (85554 4) Cartilage at the basis is necrotic and partially replaced by the ingrowing pannus Between the cartilage and the tongue of the fibrous pannus can be seen a gap which prevents the cartilage from devastating action of the pannus Hematoxylin and eosin × 40

necrosis of the superficial layers and ingrowth of the pannus tissue into the necrotic cartilage were found (Figure 7)

In the junction of cartilage of the graft with the cartilage of the bed the avascular pannus was replaced by the granulation tissue growing from the opened marrow spaces of the subchondral bone The cellular and vascular pannus filling the gap between the graft and the bed continued to replace the necrotic cartilage of margins of graft and the bed (Figure 8)

In the time between the 4th up to the 12th month the appearance of the pannus tissue practically did not change Only in disintegrated grafts were protrusions of whitish tissue found covering the defects imperfectly and only in part Histological pictures showed large islands of fibrous tissue fibrous cartilage and mature bone tissue



Figure 8 Junction of the cartilage of the bed with the cartilage of the graft 3 months after transplantation (G+3/8 H) At the left the border of the necrotic cartilage of the bed at the right the border of the necrotic cartilage of the homo graft In the centre of the picture there is cellular tissue with fine collagenous fibres The groups of cells resembling the cells of hyaline cartilage can be seen in the isthmus The fine collagenous fibres are oriented perpendicularly to the surface and near the surface parallel with it Hematoxylin and eosin × 45

DISCUSSION

During investigation of the development and ageing of traumatic pan nus three basic stages can be distinguished

1 In the first week the *primary avascular pannus* is formed It consists mostly of the network of fibrinous fibres among which numer ous erythrocytes polymorphonuclear leukocytes histiocytic and fibro-blastoid cells can be found In view of the fact that mitoses of the latter cells were observed one can take this type of the pannus for a tissue culture in a very advantageous intraarticular medium

The pannus begins to develop from the first day after the lesion of the joint surface and fills all defects resulting from the damage of the articular cartilage The extent and size of the pannus tissues not only depends on the adaptation of the graft or on the extent of the defect of articular surface but also on the function of the joint In this rela tion it makes no difference whether an autogenous or an homogenous graft was transplanted

2. In the second and third week the original avascular pannus is gradually replaced by a *cellular fibrovascular pannus*. The source of this granulation tissue is the periosteum, synovial lining and subchondral marrow spaces. This tissue is characterized by a great number of fibroblastic cells, numerous blood vessels and fine collagenous fibres. This tissue replaces the whole avascular pannus and gradually matures into a fibrous tissue.

3. Starting with the fourth week after transplantation the cellulofibrovascular pannus loses its original appearance. The number of cells and blood vessels decreases, whereas the bundles of collagenous fibres grow more numerous. Here and there islands of fibrocartilage or young bony tissue develop in the pannus. In this way a *final plastic pannus* is formed. In another case, mostly after the transplantation of homografts, resorption and defects occur in some parts of the graft. In such cases one can speak about a *lytic kind of a pannus*.

The formation of traumatic pannus not only influences the final shape of the articular surface but also its quality. The extent of final pannus is given by the extent of primary avascular pannus. This means that if a minimal primary avascular pannus is formed, the final pannus will also be a minimal one. On the other hand a large primary pannus will give rise to a large final pannus.

In all areas where the pannus has overgrown the articular cartilage this cartilage necrotizes in its superficial layers or in the whole thickness. This necrotic tissue is replaced by connective tissue or fibrocartilage.

Therefore it is important to decide when it is advantageous to support the formation of a traumatic pannus and when it is necessary to reduce its formation to a minimum.

In some experiments an effort was made, mainly after the lesion of the articular surface, to create conditions for the development of an intraarticular pannus. Krompecher (1967) removed the articular cartilage with a layer of the subchondral cancellous bone of the whole femoral portion of the knee joint and subjected such a joint to a functional load after the operation. He found that the granulation tissue growing out from the subchondral spaces was transformed into connective tissue with numerous islands of cartilage. Similar experimental arthroplasties were performed by Mooney & Ferguson (1966) and by Akeson and his associates (1969). In degenerative diseases of the joints drilling is proposed by Pridie (1959) and Insall (1967). The granulation tissue which grows out from the subchondral spaces covers the

articular surface to a limited extent and transforms into fibrocartilage In our experiments (Bartoš & Fiala 1968) we tried to improve the conditions for the rearrangement of the osseous component of the homogenous osteocartilaginous graft by means of the drilling The granulation tissue growing from the bed into the drilled holes in the graft acquired the character of a medullary pannus in the subchondral bone as described by Rutishauser & Taillard (1966)

On the other hand one tries to decrease the formation of a pannus After transplantation of the articular surface or of the whole joint we attempted to secure early function of the joint by a perfect adaptation and firm fixation of the graft In spite of early function of the joint however we were not able to keep the primary pannus down to a minimal extent In the further course it is not possible to determine whether the cellular fibrovascular pannus will acquire a plastic or a destructive form

It can be concluded that the quality of a transplanted articular surface depends not only on the reorganization of the subchondral bone but also to a certain degree on the formation of the pannus This will be a primary avascular pannus on the base of which a fibrovascular pannus and then a final plastic or lytic pannus may develop

SUMMARY

Autogenous and homogenous osteocartilaginous grafts on 90 adult mongrel dogs with the aim of reconstructing the anterior non weight bearing portion of the distal end of femur were transplanted The pannus formed by fibrin and erythrocytes filled in the first week after transplantation all the defects of the joint surface The vascular granulation tissue grew into the primarily avascular pannus from the periosteum synovial membrane or from the opened vascular spaces of the subchondral bone and changed its original structure In the areas of blood vessel penetration a rich cellular population mostly fibrocytes and fine collagenous fibres could be found This cellulofibrovascular pannus grew to maturity the collagenous fibres became thicker the cellularity and vascularity decreased and islands of fibrocartilage or osteoid tissue differentiated The cartilage overgrown by the pannus necrotized in the superficial layers or in the whole thickness and was replaced by the connective tissue or fibrocartilage At this time two forms of the pannus could be distinguished The plastic one composed of dense and strong collagenous fibres with a relatively small

amount of cells and vessels formed the folds on the cartilage or bone of the graft and bed The lytic one produced defects of the joint surface more in the graft than in the bed The possibility of supporting or reducing the pannus formation in injured or diseased joints was discussed

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TRAUMATIC PANNUS

II Changes in Hydroxyproline after an Experimental Reconstruction of the Joint Surface

F Bartoš O Fiala & J Kanta

Accepted 24 xi 72

The damage to joint surface (intraarticular fracture damage to the intraarticular structure transplantation) is followed by pannus formation The primary avascular pannus, which fills all the defects of the cartilage in the first days after the operation is later changed into the cellular and fibrovascular form The last stage of this process is the plastic or lytic form of the pannus The cytological changes accompanying the pannus formation after the reconstruction of the non weight bearing part of the joint surface by autogenous or homogenous graft have been described in the previous paper

Similar cytological changes have been observed in the reparation of artifical defects in autografts (Fiala & Bartoš 1967) We found that the drilled defects were filled with erythrocytes dispersed in the fibrin net soon after transplantation The granulation tissue formed at the bottom grew up to the surface of the defect and gradually replaced the original content of erythrocytes and fibrine Later this granulation tissue was differentiated into the cancellous bone with fat or blood marrow spaces and into the fibrocartilage at the surface

In this paper the attention was focused to one of the most important components taking part in the process of tissue healing and pannus formation—collagen This protein can be readily identified by the amino acid hydroxyproline which is found almost exclusively in collagen

METHODS

Ten adult mongrel dogs were in our experiments. The anterior non weight bearing portion of the distal articular end of the femur in the form of a osteocartilaginous autograft was transplanted Four holes 3 mm in diameter were drilled in each graft

before transplantation. The transplants were fixed to the bed with one loop of stainless steel wire. The synovial fluid, contents of the artificial holes (plugs) and pannus formed on the sides of the graft and at the junction of the graft cartilage with the periosteum of the bed, were removed 3, 7, 14 and 28 days after operation.

Samples were dried in an oven at 80° C to the constant weight. The dried tissue was hydrolyzed for 16 hours in 6N HCl at 105° C in tubes sealed under nitrogen. Hydroxyproline was determined by the method of Stegemann (1958). The values were converted to collagen equivalents using the Neumann & Logan (1950) factor of 7.46. Each point in Figure 2 presents the average of four pools from four animals. All differences (pannus plugs) are highly significant ($p>0.01$). Collagen forming has been morphologically observed in the unstained sections (10 μm) by the polarization microscope at crossed polaroids.

RESULTS

Figure 1 shows the changes in the dry weight of tissues and synovial fluid during the experiments. The dry weight of plugs was higher 3 days after the operation; other changes were not significant.

Figure 2 demonstrates the changes in collagen content. The synovial fluid contained only traces of hydroxyproline and was therefore omit-

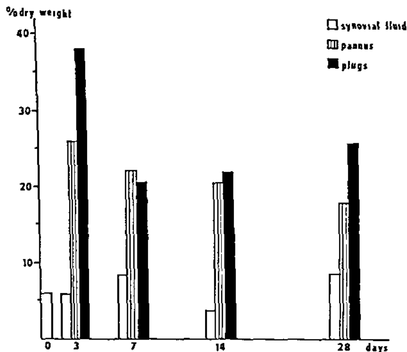


Figure 1

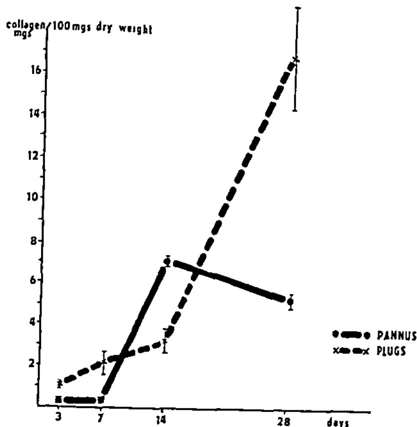


Figure 2

ted in the picture The amount of collagen in pannus was very low for the first 7 days after the operation then it markedly increased and was maintained on the same level during the second half of the experiment In the plugs the hydroxyproline content was increasing throughout the experiment first slowly later very rapidly

DISCUSSION

The results of chemical assays of collagen during the formation of traumatic pannus and healing of artificial defect in osteocartilaginous graft agree with cytological and morphological findings

In the first week after transplantation in the plugs and in the pannus itself there is very little amount of collagen because the vascular pannus is mostly composed of erythrocytes and fibrin Although there are

no collagen forming cells—fibroblasts respectively fibrocytes—we have found a certain amount of collagen in these tissues This percentage of collagen is significantly higher ($p>0.01$) in plugs which can be explained by the presence of tiny fragments of bones and cartilage The surface of the plugs closing the holes against the joint cavity is highly birefringent It is difficult to decide if there are collagenous fibres or remnants of bone or cartilage formed during the drilling of the holes in the graft

In the second week after the transplantation the increase of collagen amount in the pannus shows that the avascular form of the pannus has changed into cellular and fibrovascular tissue A rather stabile amount of collagen in the pannus 28 days after transplantation can be explained by the incomplete pannus separation after opening the joints In this time the pannus adheres strongly to bone or cartilage and it is not possible to remove the whole pannus without damaging the bottom For this reason only the superficial and younger parts of the pannus containing less collagen were taken and then examined

The slow increase in collagen occurring in plugs for 14 days after the transplantation and the later rapid increase fully correspond with the morphological changes during the reparation of defect in the osteocartilaginous graft (*Fiala & Bartos 1967*) Fourteen days after the transplantation the tissues filling the defect may be divided into three zones The deepest layer is formed by the granulation tissue with the osseous framework at the bottom The middle layer contains a lot of macrophages and erythrocytes with fine fibrinous fibres The superficial layer is composed from the net of fibrinous fibres with erythrocytes among them On the surface of this zone there is a dense net with doubly refractive contents The microscopical arrangement of the plug shows that the collagenous fibres can be found only in the basal zone On the contrary the pannus situated on the side of the graft is penetrated by the granulation tissue in its whole thickness during this time

Four weeks after the transplantation the defect in the graft is filled up either with granulation tissue or with bone trabecullae for which reason the amount of collagen in plugs is so high

The determination of hydroxyproline in the formation and ageing of the pannus supported the macroscopic and microscopic findings after the *transplantation of osteocartilaginous graft* This determination verified as well the division of the pannus into the basic two forms the primary avascular form which is mainly formed by fibrin

and erythrocytes and the cellulovascular form that is presented on the other hand by the collagen forming granulation tissue

SUMMARY

The authors transplanted the anterior portion of the distal articular end of the femur in the form of perforated osteocartilaginous autograft in dogs The amount of hydroxyproline in the pannus forming either on the sides of the graft or in the artificial defects was determined The authors found that in the first week the content of hydroxyproline in the pannus was minimal and increased in the second week after the transplantation when the primarly avascular pannus was transformed into the cellulo-fibrovascular form

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A CASE OF AGENESIS AND A CASE OF RUPTURE OF THE PECTORALIS MAJOR MUSCLE

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Accepted 15 ix 72

AGENESIS

Agenesis or hypoplasia of the pectoralis major muscle is rare In such cases the sternocostal and abdominal parts are most often lacking The cranial portion pars clavicularis is the first to develop in the foetus Inhibition of further development explains the occasional lack of the two other parts This muscular defect can be a singular malformation or can be combined with other malformations both musculo skeletal and cardio pulmonal (Thorsrud 1968)

The clinical significance of this muscular defect apart from the cosmetical aspect is little

The role of the pectoralis major is primarily that of adduction and internal rotation With the arm abducted the muscle fibres run obliquely and pull the arm forwards as in swimming When the arm is raised over the horizontal plane all parts of the muscle exert the same effort of lowering the arm powerfully as for example when striking with an axe If both arms are fixed shifting the punctum fixum and punctum mobile the pectoralis major acts as an accessory breathing muscle

Case Report

A six year old boy came to the clinic because of flat feet On examination the sterno costal part of the pectoralis major muscle was found to be lacking on the left side All other shoulder muscles were normal The left mammilla was also lacking An X ray plate of the thorax showed flattening of the ventral aspect rendering the sagittal diameter shorter on the affected side

RUPTURE

Few cases of rupture of the pectoralis major muscle have been recorded and all have occurred in well trained athletes (Marmor et al 1961)



Figure 1



Figure 2

Case Report

A 28 year-old wrestler complained of pain in his left shoulder after a match He had been a wrestler for the previous 14 years Four weeks before admission to hospital his left arm had been caught under the training mat and his body flung over to the opposite side by his compan on

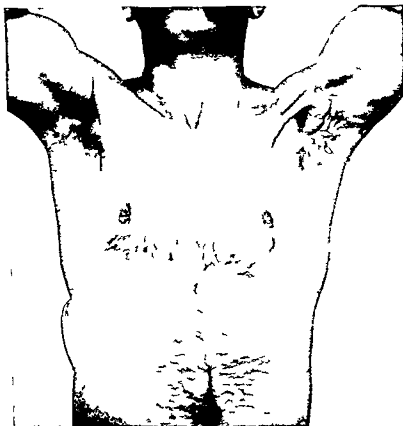


Figure 3

On clinical examination he was found to have local tenderness over the belly of the left pectoralis major muscle and thinning of the axillary fold with widening of the axilla and weaknes of shoulder function Skeletal X ray exam nation of the shoulder was normal and X ray films of the soft tissues" failed to show any changes in the pectoralis shadow

Surgical repair was not tried in this case because it is said that operative treat ment of this type of rupture does not give any considerable improvement as in cases where avulsion of a bone fragment takes place (Marmor et al. 1961)

The wrestler took up training a few weeks after the injury He experiences little difficulty in his daily work as construction worker but refrains from any wrestling matches

DISCUSSION

It has been shown by McMaster (1933) that a normal tendon does not rupture and that the tendon can sustain considerable injury before it

breaks Instead either the tendon insertion or muscle origin gives way often detaching a small fragment of bone or the muscle belly ruptures or the musculo-tendinous junction separates Numerous other clinical examples of the great tensile strength of tendons have been reported

In accordance with the findings of Ralston et al (1949) a muscle can sustain about four times as much weight as it can lift that is the maximum force of a muscle is a certain percentage of its isometric tension illustrated by the formula $(P + a)(v + b) = \text{constant}$ where P represent load v velocity, b is a constant having dimensions of velocity and a the shortening heat per unit shortening having the dimensions of force This is shown in muscles having cineplastic tunnels

According to the patient s history the above case of rupture occurred when the arm was contracted with maximum force and the patient s body thrown during the wrestling This represents an indirect type of trauma exerted along the entire musculo-tendinous unit

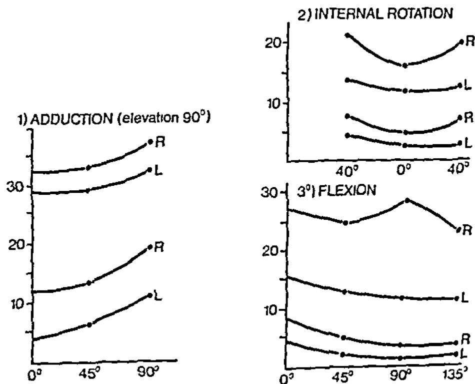


Figure 4 Graphs 1–3 Tension in pounds in isometric contractions at various angles Higher values case of rupture lower values agenesis

from origin to insertion causing the separation of the musculo tendinous junction

As it could be of interest to determine the loss of strength of those movements of the shoulder that required the sternal portion of the pectoralis major the isometric contraction power in adduction, flexion and internal rotation was tested in both patients

The graphs give very similar pictures of the difference in strength As expected the power is markedly decreased in flexion and internal rotation

CONCLUSIONS

1 Full range of movements is possible in the shoulder without the pectoralis major muscle
2 Marked decrease in flexion power and internal rotation power is seen in agenesis and after rupture of the pectoralis major muscle limiting sporting activities and strenuous work
3 A normal tendon does not rupture except at the musculo tendinous junction or tendon insertion
4 X ray pictures of the chest in an individual with agenesis of the pectoralis major shows flattening of the ventral aspect
5 *The musculo tendinous rupture should be allowed to heal by itself*

SUMMARY

Two pathological conditions of the pectoralis major muscle agenesis and rupture are presented The tensile strength of tendons and the mechanism of rupture of the musculo tendinous unit are described Graphs showing the components of decreased muscle power have been drawn The different aspects of treatment of rupture of the pectoralis major muscle are briefly discussed

ACKNOWLEDGEMENT

I wish to express my thanks to Gosta Frykman M D Associate Chief of the Orthopedic Surgical Dept Vasterås for his valuable help and advice during the preparation of this paper

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INTERTROCHANTERIC OSTEOTOMY WITH A O TECHNIQUE IN ARTHROSIS OF THE HIP

F Wang Hansen Chr Hansen Leth & E Gert Jensen

Accepted 27 ii 72

Osteotomy of the upper end of the femur in treating arthrosis of the hip was first reported by McMurray (1935) He applied osteotomy above the lesser trochanter with medial displacement of the femoral shaft and immobilization for four to six months in hip plaster of Paris

Since then a number of methods have been described for internal fixation Blount (1943 1964) and Kessel (1955) use straight splints the upper ends of which are tapped into the greater trochanter and the bottom ends of which are fixed to the femur with screws

Osborne (1969) and Wainwright (1971) supplement this with a screw at right angles to the upper part of the splint and this allows for applying compression on the site of osteotomy and a more stable fixation Tillberg (1968) uses collum nails and splint to maintain a large surface of contact in the osteotomy

The A O technique described by Muller et al (1969) introducing the use of angulated splints fixed under compression makes allowance both for the demand for stable fixation and the wish for a wide contact surface Since 1968 we have used this method and found it well suited The purpose of this post examination has been to assess the healing of the osteotomy when this method of fixation is used and to evaluate the primary results of the operation regarding its pain relieving effect

MATERIAL AND METHODS

The present analysis comprises the results of 96 intertrochanteric osteotomies performed in the Copenhagen Orthopaedic Hospital Departments I and II during the period from May 1 1968 to May 1 19 0 It contains all intertrochanteric osteotomies performed on patients with arthrosis of the hip 92 patients were operated on 56 women and 36 men 53 patients were operated on the right side 43 patients on the left side

Table 1 Age distribution in 92 patients treated with intertrochanteric osteotomy with AO technique

Age (years)	No of patients
Under 20	2
20–30	2
31–40	5
41–50	9
51–60	32
61–70	36
71–80	6
	92

During the period in question a total of 268 operations were made for arthrosis of the hip Arthrodesis was carried out in 36 cases arthroplasty in 84 cases and other minor operations (inforatio coxae resectio n obturatorii) in 52 cases.

In all patients the main symptom was pain The indication for osteotomy was a fairly well preserved hip joint on X rays and a reasonable range of flexion as a rule more than 60

Table 1 shows the age distribution The youngest patient was 18 years old the



Figure 1 Antero-posterior radiograph of hip immediately following intertrochanteric osteotomy with medial displacement



Figure 2 Radiograph showing the result of intertrochanteric osteotomy with angulation in varus and external rotation of femur

oldest 76 The majority of the patients were between 51 and 70 years old (74 per cent) Of the 95 operated hips the arthrosis was secondary in 33 cases, which means that a causative factor could be proved as e.g prior fracture or epiphysiolysis with caput necrosis sequealae of mb Calve Perthés or prior coxitis In the 63 cases such predisposing factors could not be proved

Thirty two of the patients had two sided arthrosis whereas in 60 cases the changes were predominantly or completely one sided

In all patients the mobility of the hip was limited prior to the operation The range of flexion movement was used as a criterion for mobility and in 52 of the cases preoperative hip flexion of 90 or more was found In 43 patients the hip flexion was less than 90 In one case the preoperative mobility was not examined as the osteotomy was performed simultaneously with acute operation for fractured femoral neck.

In all of the patients femoral osteotomy had been performed transversally above the lesser trochanter accompanied by medial displacement (Figure 1) changed collum angle or rotation possibly a combination of the e variations (Figure 2) All the osteotomies are fixed with angulated A O splints with compression according to the technique described by Muller et al (1969)

In 46 patients the position of collum was changed. In 50 cases only medial dislocation on the site of osteotomy was performed Of the 50 osteotomies comprising medial displacement exclusively dislocation of less than 5 mm was found in 17 cases Only in 8 cases did the dislocation exceed 10 mm

Postoperatively pool exercises were started when the wound had healed and three weeks postoperatively the patient was allowed to stand gently on his leg.

RESULTS

The period of observation varied from six months to three years (Table 2) All the osteotomies were radiologically healed during the time of observation

Delayed healing included radiological failures i e no fuzzy line of osteotomy and no continuous columns of bone after four months Delayed healing was observed in 7 patients In 3 of these cases the clinical course was normal Radiological obliteration of the line of osteotomy only occurred seven eight and twelve months after the operation

Three patients were re operated 2 of them after three months and the third one after five months, all due to increasing clearing along the line of osteotomy At the re operation another angulated splint was applied, and then the osteotomies healed normally

Table 2 Time of observation of 95 intertrochanteric osteotomies with A O technique

Observation time	No of cases
6–12 months	40
12–18 months	34
18 months–2 years	13
2–2½ years	7
2½–3 years	1
Total	95

Table 3 Complications in 96 intertrochanteric osteotomies with A O technique

Type of complication	No of cases
Pseudarthrosis	0
Delayed healing	7
Angulation in varus position	4
Fractured collum or trochanter	4
Wound infection	4
Postoperative bleeding	1
Bronchopneumonia	3
Lung infarction	4
Coronary occlusion	1
Thrombophlebitis	5

The last case of delayed healing occurred in connection with fracture of the femoral neck during the convalescence period

One month after the operation a 67 year old man had pains in the operated hip No recognized trauma was recorded Radiography showed a vertical fracture laterally in the collum While the patient was bed ridden the fracture healed in normal time whereas the line of oste otomy had only vanished after eight months

In four patients unintended angulation in varus appeared post operatively In 3 of the cases the angulation occurred simultaneously with and probably caused by fracture in the collum or the greater trochanter In the fourth patient the osteotomy was fixed with a 110 angulation splint instead of the correct 90 splint and already during the application varization set in Two of the above mentioned patients were treated with plaster of Paris for two months In the remaining 2 cases the time of weight bearing was delayed two and two and a half months after the operation All 4 osteotomies healed by the end of three months after surgery

Postoperative wound infection occurred in 4 patients in all cases a minor infection which did not affect healing of the bone In one case the splint was removed two months after the operation and the oste otomy had then healed In none of the 4 infected cases did the time of healing exceed three months

Postoperative bleeding causing revision of the hemostasis on the same day occurred in one patient Defect in coagulation has not been proved

There were 3 cases of postoperative bronchopneumonia and 4 lung infarctions all minor cases These 4 patients together with 4 patients with deep thrombophlebitis were given anticoagulation therapy Pre operative anticoagulation therapy has not been applied

One patient died five months after the operation as a result of hemo lytic anemia with splenomegaly possibly caused by myeloid leukemia

In 22 cases the A O device was later removed partly because of pain which could be ascribed to the splint partly because of clearing around the splint or screws on the radiographs In one patient the splint caused coxa saltans

The time from the operation to the onset of radiological healing appears from Table 4 In 68 cases i e 70 per cent of the total the oste otomy healed in less than three months In 6 patients the time of healing cannot be included in this report as radiographs from the period of healing are not available These 6 patients had a normal

clinical course and subsequent radiographs showed healing of the osteotomies

Table 4 Roentgenologic time of healing for 96 intertrochanteric osteotomies with AO technique

Healing time	No of cases
Less than 2 months	40
Less than 3 months	28
Less than 4 months	15
Over 4 months	7
Unknown	6
Total	96

Table 5 Statements of 95 patients concerning the pain relieving effect on the hip pain in intertrochanteric osteotomy with AO technique

Results	No of patients
No pains	61
Slight pains	21
Unchanged pains	7
Other pains	6
Total	95

The primary effect of the operation on pain was assessed according to the patients statements at the post examination (Table 5) 82 patients stated that the preoperative pains had vanished or considerably decreased and only 7 patients reported that the pains were unchanged or worse In 6 patients other pains occurred which could be ascribed to the apparatus to a simultaneous spondylosis or to arthrosis of the knee joint Altogether 90 per cent of the patients reported improvement of the preoperative pain

If the patients statements concerning the effect of the operation are compared to the type of operation (Table 6) no difference can be shown Thus the immediate effect of the operation seems to be related to the osteotomy rather than to the changed conditions of load

Whether the further course of the arthrosis is influenced cannot be decided on the present basis

In the majority of the patients the mobility range was unchanged after the operation (Table 7) In 30 patients however the mobility was improved by more than 10 possibly due to reduction of the muscle spasm caused by pain

Previously it has been found that in cases of strongly reduced mobility of the hip osteotomy certainly has an almost equally good pain relieving effect but also a considerable tendency towards further reduced hip mobility

Table 6 The distribution of the pain relieving effect on osteotomies with exclusively medial displacement and other combined osteotomies

	Osteotomies with exclusively medial displacement	Combined osteotomies
No pains	33	28
Slight pains	9	12
Unchanged pains	4	3
Other pains	3	3
Total	49	46

Table 7 Hip mobility following intertrochanteric osteotomy with A O technique compared with the preoperative mobility and stated by range of flexion movement

Results	No of cases
Improved mobility	30
Unchanged mobility	45
Less mobility	19
Not reported	1

If the mobility is examined after the operation in the patients with the most considerably reduced mobility preoperatively it will appear that in these 43 patients the mobility was only further reduced in 6 cases while in the remaining 37 cases it was unchanged in 16 and improved in 21 cases

DISCUSSION

In intertrochanteric osteotomy the greatest problem connected with the methods of operation has been sufficiently stable fixation. Osborne (1969) and Wainwright (1971) used compression for obtaining this. With the A. O. technique both rigid fixation and a large area of contact at the osteotomy site is obtained.

The purpose of this work was to evaluate whether the A. O. technique has brought about a method of fixation which in spite of early weight bearing is sufficiently stable to provide safe healing.

The evaluation of the radiological healing is made difficult by the fact that periosteal callus appears sparsely in connection with a compression that is satisfactorily applied. Jerri & Tilling (1969) found callus in 15 out of 35 osteotomies without compression after two months and in all 35 cases after four months, but complete obliteration of the line of osteotomy was only seen after six months in one third and after nine months in two thirds of the cases.

In this work the criterion of healing was the occurrence of continuous columns of bone and obliterated line of osteotomy. Using this we found 68 out of 96 osteotomies (= 70 per cent) healed after three months and 83 (= 86 per cent) by the end of four months. Lucht & Tarp (1967) using the Bosworth splint found healing in 72 per cent of 57 osteotomies after three months.

In the cases with no signs of healing after four months 5 out of 7 cases concerned combined osteotomies (dislocation + angulation etc.) where optimal contact on the site of osteotomy is difficult to obtain. This was also the case in the 4 patients where secondary angulation in varus occurred. Lowe (1969) using a modification of the Muller technique found that delayed healing mainly occurred in cases of varus osteotomy. Stainsby & Mukarjee (1969) who used the same technique found that increased angulation in varus occurred in 23 of 58 osteotomies and varus angulation occurred when the dislocation was more than half the bone width.

The pain relieving effect of the osteotomy has been investigated earlier. Jerri & Tilling (1969) found reduced pains in 100 per cent, Adam & Spence (1958) in 81 per cent and Lucht & Tarp (1967) in 95 per cent. This examination showed that in 88 patients or 90 per cent of the cases the osteotomy brought about relief or considerable reduction of pain. The time of observation was short so the results can only be preliminary, but they do not seem to differ from what has previously been found.

Earlier investigators have had differing opinions concerning the meaning of changed collum axis and the degree of medial dislocation in the osteotomy In connection with the original McMurray osteotomy medial dislocation is combined with valgus position of collum Blount (1964) stated that simple transversal osteotomy does not reverse the degenerative processes whereas Lucht & Tarp (1967) and Adam & Spence (1958) found that the pain relieving effect of the osteotomy was independent of the medial dislocation Kallio & Klossner (1967) stated that the result of the osteotomy is better if the medial dislocation exceeds half the width of the bone and simultaneous varus or valgus angulation is performed whereas Scott (1967) found that dislocation exceeding half the width of the bone and varus angulation caused increased risk of pseudarthrosis

As stated in Table 6 the pain relieving effect of the osteotomy seems to be the same whether simple osteotomy is performed or the axis of collum is changed simultaneously In most cases the medial displacement was less than 1 cm Due to the shape of the apparatus it is possible to make minor dislocations on the site of osteotomy and thus maintain the largest possible contact

The early mobilization does not seem to have delayed healing No cases of pseudarthrosis were observed whereas other investigations as reported by Jerri & Tilling (1969) showed pseudarthrosis frequencies between 3 and 28 per cent

As previously stated the A O device was eventually removed from 22 patients often due to pain originating from the splint Also Lowe (1969) found that the inserted material may cause discomfort in the form of pain In one third of the patients he noted complaints about the inserted splint and likewise Stainsby (1969) found such symptoms in 24 of 58 patients

SUMMARY

In the Orthopaedic Hospital Copenhagen Departments I and II intertrochanteric osteotomy for osteoarthritis of the hip was performed in 92 patients (a total of 96 intertrochanteric osteotomies) with the A O technique during the period from May 1 1968 until May 1 1970 The osteotomy was performed above the lesser trochanter and accompanied by medial displacement on the site of osteotomy or change of the collum angle None of the patients died in relation to the operation All the osteotomies healed Delayed healing occurred in 7 cases

In 3 of the cases the clinical course was not influenced by the slow healing. Three patients were re-operated and the splint exchanged after which there was normal healing. Unintended angulation in varus occurred in 4 patients, in 3 of the cases accompanied and probably caused by fracture in the femoral neck or greater trochanter. The device was later removed in 22 patients due to discomfort or clearing around the splint or screws.

Post examination showed that the preoperative hip pains had completely disappeared in 61 patients, considerable relief was noticed in 27. In 7 cases the pains were unchanged.

With a sufficiently simple technique the A.O. method in trochanteric osteotomies brings about rigid fixation which allows for rapid mobilizing of the patients. Disturbed healing occurs only seldom and the pain relieving effect seems to correspond to the results obtained by other methods.

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PARA ARTICULAR OSSIFICATIONS AFTER TOTAL HIP REPLACEMENT

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Accepted 20 x 72

The preoperative and postoperative complications of alloarthroplasties of the hip are virtually the same with all types of prosthesis (McKee 1951 1966 1969 Friedebold 1969 Charnley 1969 Watson Farrar 1969 Watt 1969 Chapchal Muller 1970 Weber 1970 Chapchal 1972) In the past three years in particular para articular ossifications have been increasingly mentioned in this respect (Boitzy Zimmerman 1969 Huggler 1969 Willert Semlitsch 1970 Cotta Schulitz 1970 Kingma 1971 Owen 1971 Ring 1971 Chapchal 1972 Slooff Van Berkel 1972 Blaimont 1972 Wilson et al 1972 Murray 1972 Patterson et al 1972) On clinical grounds—course localization and radiological features—these heterotopic ossifications can be brought under the heading of non septic ectopic ossifications of the locomotor apparatus These can be divided into ossifications in tendons particularly those of the hip adductors (McLean Urist 1961) congenital myositis ossificans progressiva (Noble 1924 Frejka 1929 Mann Singh 1967) myositis ossificans circumscripta which is usually posttraumatic (Geschickter 1938 Thorndyke 1940 Leventhal Kaplan 1962 Urist McLean 1963 Paterson 1970) and the para osteoarthropathies observed in association with neurological disorders especially paralyses (Dejerine Ceilher 1919 Miller O Neill 1949 Brailsford 1911 Irving Le Brun 1951 Hardy Dickson 1963 Roberts 1968 Costello-Brown 1951 Gunn Young 1959) The latter mostly occur around the large joints and specifically around the hip and elbow To this list we should like to add the ossification around the hip alloarthroplasty

The aetiology and pathogenesis of ectopic ossifications are obscure The oldest theory is probably that of Dejerine & Ceilher (1919)

who assumed that metaplasia of primitive connective tissue should be held responsible Leriche & Policard (1926) suggested that haemorrhages and inflammations (e g rheumatic affections) stimulate the connective tissue to heterotopic ossification Friedenstein (1966 1969) and Danis (1970) held that migrating bone marrow cells cause the change of connective tissue elements into osteogenic tissue A traumatic cause was accepted by Geschickter (1938) Ackermann (1958) and Collins (1965) who believed that lesions of muscles or interstitial haemorrhages can lead to degeneration of muscle proliferation of perivascular connective tissue and ultimately to formation of cartilage osteoid and bone Urist & McLean (1963) and Zaccalini & Urist (1964) suggested that a periosteal lesion causes such changes in local cell metabolism that differentiation of osteogenic cells occurs leading to ossification

While there are only hypotheses on the cause of these ossifications their histomorphological features and course are well known The histological descriptions of myositis ossificans progressiva (Frejka 1929 Maini Singh 1967) and of other types of ectopic ossification (Urist & McLean 1963) show close similarities The heterotopically induced bone matures and via various stages ultimately begins to resemble normal trabecular bone Radiologically too matured ectopic bone resembles normal bone tissue

MATERIAL AND METHODS

In a follow up study of 155 patients submitted to total hip replacement during the period 1969–1971 emphasis was placed on the occurrence of ectopic ossifications (Figure 1)

Efforts were made to classify these cases according to the localization and severity of ossification and to compare these with the therapeutic results The clinical course was analysed Biopsy specimens were used for histological examination A preliminary impression was gained concerning therapy with phosphonates

The study encompassed 200 hips in 155 patients with the following distribution

males	31	left sided	51
females	124	right sided	59
		bilateral	45
total	155 patients	total	155 patients

The graph in Figure 2 shows the age distribution

We used two types of prosthesis for hip replacement the Muller type (63 cases) and the McKee type (137 cases) The operative approach was anterolateral for the



Figure 1 Para-articular ossification

Müller type and posterolateral for the McKee type. Both types of prosthesis were cemented with Palacos R. The joint-capsule was excised in toto

Postoperative treatment and after-care were the same for both types of prosthesis

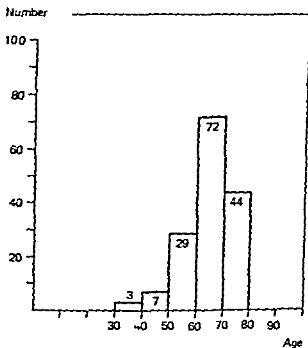


Figure 2 Age distribution

and encompassed (1) wound drainage during 48 hours (2) a hip pica during 5 days (3) traction in abduction and extension during 5 days

From the first postoperative day (1) anticoagulant medication (2) isometric static exercise of the limb involved

Wound dressing on the 5th postoperative day and walking with two English canes without weight bearing

From the 10th postoperative day active hip exercises and exercises with weight bearing

The indications for the arthroplasties were the following

progressive coxarthrosis	149
secondary head necrosis	10
rheumatism	10
Bechterew s disease	1
unsuccessful preceding hip operation	30
	200

osteotomy	17
Moore prosthesis	7
Smith Petersen cup	3
total hip	2
arthrodesis	1
	30

Grading of Ossifications

For greater convenience four grades of ossification were distinguished (Figure 3) on the basis of the following parameters (1) localization and extent of ossifications (2) intensity and structure in radiographs

The grades can be defined as follows

Grade 0 no ossifications

Grade I only in the gluteal area not clearly defined in radiographs and without distinct bone structure

Grade II in gluteal and psoas areas again ill defined but with a more distinct structure

Grade III complete bony bridge between femur and pelvis both in the gluteal and in the psoas area structure like that of normal bone

RESULTS OF FOLLOW UP

The 200 arthroplasties are arranged below according to the above grading of ossifications

Ossification grade	No of hips
0	95
I	49
II	42
III	14
	200



Grade 0 Grade I



Grade II Grade III

Figure 3 Grading of ossifications

The 14 cases of severe para articular ossification were evenly distributed over the two types of prosthesis In all patients treated by bilateral operations bilateral ossifications were found but this does not mean that the grade of ossification was the same on both sides The relation between operative indication and occurrence of ossifications is shown in Table 1

Table 1

Indications	preoperative	*Ossifications* postoperative 0	I	II	III
coxarthrosis	0	71	37	32	9
secondary head necrosis	0	2	2	3	3
rheumatoid arthrotis	0	10	0	0	0
Bechterew s disease	0	1	0	0	0
osteotomy	0	0	8	7	2
Moore prosthesis	0	6	1	0	0
Smith Petersen	0	3	0	0	0
total hip	0	2	0	0	0
Bracket arthroplasty	0	0	1	0	0
		95	49	42	14

Table 2 indicates the correlation between grade of ossification and postoperative hip function as compared with the preoperative condition

Table 2

Function	Improved	Unchanged	Reduced
Grade 0	85	8	2
Grade I	33	14	2
Grade II	20	18	4
Grade III	2	3	9
	140	43	17

The Grade III ossifications lead to further reduction of the hip function after operation Grade I and Grade II ossifications hardly affect postoperative function However Grade III ossification need not necessarily preclude movement This is demonstrated in Figure 4 showing radiographs of a hip in abduction and adduction

The following *clinical* and *radiological* findings support a diagnosis of Grade III para articular ossification



Grade 0 Grade I



Grade II Grade III

Figure 3 Grading of ossifications

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Moore prosthesis	0	6	1	0	0
Smith Petersen	0	3	0	0	0
total hip	0	2	0	0	0
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Figure 4a Abduction and adduction radiographs



Figure 4b Collateral radiograph

Clinical Findings

1 Persistent pain in the hip involved of a nature different from that of wound pain
2 Slight swelling of the hip
3 Progressive limitation of passive and active hip movements
4 No fever redness or signs of infection

Radiological Findings

After 2–3 weeks the gluteal area shows an irregularly defined densification of somewhat mottled appearance which later becomes homogeneous

The total bridging takes about 12 weeks the structure becoming more and more that of normal bone

Histological Aspects

In a few cases biopsy material from the ossification was submitted to histomorphological examination The process of ossification proved to resemble that also seen in myositis ossificans and in para osteo arthropathies *Mainly through desmal ossification the osteoblasts pro* duce osteoid which is normally mineralized A woven bone structure results which is later changed to trabecular bone The features observed closely resemble those of desmal ossification in callus formation The biopsy specimens contained no muscle cell remnants and we observed no sarcomatoid features of the type so often described in myositis ossificans

Serum Determinations

In the group of severe para articular ossifications we observed a distinct increase in serum alkaline phosphatase The increase occurred 3 weeks after the operation—at a time corresponding with the first radiological evidence of ossifications Serum calcium and serum phosphate concentrations did not change when ossifications occurred nor were the CPK (creatine phosphokinase) and LDH (lactodehydrogenase) levels increased in association with ossifications There was no correlation between the ESR (erythrocyte sedimentation rate) and the occurrence of ossifications

THERAPY

There is no known therapy of para articular ossifications and the literature has so far failed to present even acceptable suggestions in this context It seems that the ossification will have to be accepted as *an inevitability which sometimes (in about 7 per cent of cases) leads* to loss of function

As has been described for para-osteoarthropathies early radio therapy might be considered in these cases also Again as in para osteoarthropathies surgical resection might be contemplated after maturation This is in contrast with the results in myositis ossificans progressiva where resection is useless even in a stationary stage because a relapse nearly always occurs

Our experience has so far been limited to early physiotherapy which although it cannot prevent ossifications can at least ensure continued mobility because what might be described as a pseudarthrosis develops in the ossifications

Clinical reports on the use of EHDP in myositis ossificans (Bassett et al 1969 Russell et al 1972) and in Paget s disease (Smith et al 1971 Bijvoet 1972) based on findings reported by such authors as Fleisch (1966 1969 1970) and Francis (1969 1971) prompted us to try EHDP (ethylhydroxydiphosphonate) in these cases also Its administration proved futile when ossifications were already present we therefore decided to use EHDP preventively We have already observed that preventive administration from the day of the operation cannot prevent ossifications In collaboration with Dr Bijvoet (Department of Internal Medicine) we have recently given a number of patients awaiting total hip replacement EHDP during 6 preoperative weeks while an equal number received a placebo Medication was continued through 2 postoperative months The results of this procedure are not yet ready for a definite conclusion It is to be noted however that patients who had already developed unmistakable ossifications after a unilateral operation without EHDP did not develop an ossification when the contralateral hip was replaced with EHDP protection The results of this study await further evaluation

Our understanding of the aetiology of these ossifications should also be improved but it is not within the scope of this report to discuss experimental work in this context

SUMMARY

This paper discusses the para articular ossifications after total replacement This led to serious loss of function in 7 per cent of cases The ossifications are radiologically visible from the 3rd week after the operation and give rise to clinical symptoms Ossification on one side implies the occurrence of ossification after contralateral hip replacement The aetiology is obscure The histological features are those of desmal ossification of the type also observed in myositis ossificans in paraosteoarthropathies and in fracture healing Therapy should be preventive and there are indications that EHDP may yield favourable results in this respect

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ROTATIONAL DISPLACEMENT AFTER PERCUTANEOUS INTRAMEDULLARY OSTEOSYNTHESIS OF FEMUR SHAFT FRACTURES

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Accepted 28 xi 72

In the Department of Surgery intramedullary osteosynthesis according to the specifications of Kuntscher (1962) was the standard method of operative treatment of shaft fractures of the femur and the tibia The displacement of the main fragments was readily reduced by stable intramedullary osteosynthesis except for the rotational displacement —*dislocatio ad periferiam*—especially when the osteosynthesis was done percutaneously in femur shaft fractures The percutaneous intramedullary osteosynthesis as described by Kuntscher (1962) and Muller et al (1963) was practised more frequently when a roentgen television set became available in 1964

The percutaneous method of osteosynthesis made an exact roentgenological method desirable for the calculation of the rotational dislocation The anteversion angle (AV) of the left and the right neck of the femur is normally equal Any obvious difference after a unilateral shaft fracture therefore indicates a rotational displacement of the main fragments (Muller 1967)

The present study was undertaken to establish a roentgenological method for the calculation of the AV angle of the neck of the femur and thereby the rotational displacement in unilateral femur shaft fractures The method of Dunlap et al (1953) modified by Rippstein (1957) was chosen for this purpose The methods of Normann (1965) and Edholm (1966) were later also evaluated

MATERIAL AND METHODS

Ten hospitalized patients with clinical and roentgenological normal hip joints and without any bone fracture were used as a reference for the roentgenological method

Fourteen patients with unilateral femur shaft fractures treated by intramedullary clover leaf nails were examined clinically and roentgenologically in 1967 and six *of them roentgenologically one year later* The youngest patient was eight the oldest 44 years of age mean 17 9 years SV ± 9 3 Ten patients had transverse two longitudinal fractures in the middle third of the shaft and the adjoining part of the distal third Two had comminuted fractures in the same parts of the shaft making stable intramedullary osteosynthesis impossible All fractures were closed with marked displacement but without additional soft tissue damage Eleven were nailed by percutaneous three by open technique

In all patients the AV angle of the neck of the femur was calculated in accordance with the specifications of Rippstein (1955) The apparent anteversion (AV) angles in the roentgenograms were measured with a roentgen ischiometer in accordance with Muller (1957) The true AV angles were calculated from the apparent ones using the conversion table of Rippstein (1955) The roentgenological methods of Normann (1965) and Edholm (1966) were used in a few patients (not included in the present material)

RESULTS

The positioning stand and the roentgen ischiometer (Protek AG Bern Switzerland) were easily adapted for routine work The AV angle of the neck of the femur was—for practical purposes—almost identical on the right and the left side in the ten patients without any fracture (Figure 1 a)

In the fracture patients some difference was found—indicating an *uncorrected rotational displacement—between the calculated AV angle* of the fractured compared to the nonfractured side (Figure 1 b)

By repeated roentgenological examination after one year practically no difference in the AV angle was revealed in six fracture patients (Figure 2)

Only three patients—denoted by stars in Figure 2 b—had by clinical examination obvious rotational displacement of their shaft fractures One had an internal two an external rotational displacement and also a retroversion (RV) of the neck of the femur on the fractured side

The first patient coordinates (24) 40 in Figure 1 b was a 16 year old male The transverse fracture had been nailed by the open method Nevertheless the true internal rotational displacement was 21 roentgenologically

The second patient coordinates −6 (18) was a 15 year old male with a comminuted shaft fracture In order to correct angular and transverse displacement a thin Küntscher nail was inserted percutaneously The fracture had supplementary external fixation till it healed with considerable shortening. The true external rotational displacement was 26

The third patient coordinates (9)–13 was a 25 year old female also with a

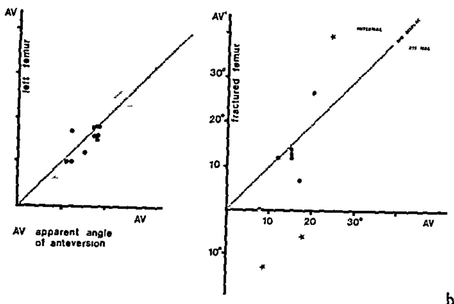


Figure 1 a Normal group *(10 patients) The apparent angle of anteversion (AV) of the left (ordinate) and the right neck of the femur (abscissa) gives the patient's coordinates in the scatter diagram The distance from the 45 axis gives the difference in the measured AV angle between the two contralateral sides One measurement only reveals a larger difference than ± 3 between the left and the right side*

Figure 1 b Fracture group *(14 patients) The AV angle of the fractured (ordinate) and of the non fractured side (abscissa) gives the patient's coordinates By selecting the patients coordinates as shown in the scatter diagram all patients with internal rotational displacement are found over and all with external displacement under the 45 axis External displacement was most often found Few had a larger displacement than ± 10 (apparent) Three patients with larger rotational displacement—denoted by stars—are especially commented on in the text*

retroversion of the neck of the femur on the fractured side This was due to a true external displacement of 25 Painful muscular strain developed in the hip region on the same side postoperatively The pain became worse with increasing weight bearing The Trendelenburg sign was positive on the affected side The proximal end of the nail protruded somewhat over the medial side of the greater trochanter Five months after the operation roentgenograms demonstrated absorption around the perifery of the nail in the distal fragment indicating instability

The patient's complaints were ascribed to the instability of the fracture and the protruding end of the nail The patient was therefore reoperated by percutaneous technique The rotational displacement could not be successfully reduced by this approach The transverse fracture healed after the rigid reosteosynthesis but the patient experienced—as before—low grade pain in the medial side of the affected thigh toward the knee The leg and the foot had a tendency of outward rotation when walking

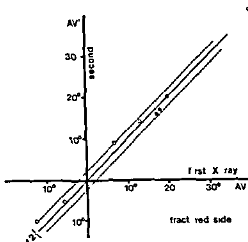


Figure 2 The reliability of the AV angle measurements of six of the patients in the fracture group is shown in this scatter diagram The AV angle measured on the first roentgenogram (abscissa) and the same angle measured on another roentgenogram of the same neck of the femur one year later (ordinate) gives its coordinates The diagram reveals some small systematic error of measurement probably due to replacement of the homemade positioning apparatus by one of industrial designs

DISCUSSION

Femur shaft fractures can more easily be aligned by open intramedullary osteosynthesis than by percutaneous approach The open method thus simplifies the operative procedure and requires less instruments than the closed percutaneous method It also gives the choice during the operation of using the internal appliance which gives the best possible internal fixation

The open method usually imposes a larger operation on the patient It always makes a closed fracture open with the risk of infection and additional soft tissue and periosteal damage which may give delayed union and sequelae

Percutaneous intramedullary osteosynthesis is advocated by several authors (Kuntscher 1962 McDonald 1968 Bohler 1968 Rokkanen et al 1969) As the fracture is not directly exposed there is much less risk of infection even if the fracture is open (Bohler 1968) By this method the operative trauma ought to be at a minimum leading to a more rapid and uneventful recovery (Rokkanen et al 1969)

However the percutaneous method imposes several difficulties partly on the technical equipment partly on the more precise and stereog

nostic use of these Without a minimum of instruments including a roentgen television set, the percutaneous method cannot be done safely

The choice of internal appliance is usually restricted to the intra medullary nail which can only give a rigid osteosynthesis in the middle part of the shaft in fractures with no tendency of shortening Lastly reducing the rotational displacement *ad integrum*, is unlikely

Some *rotational displacement* is usually well tolerated after femur shaft fractures In our selected material only one patient had com plaints Weigert et al (1968) report more disabling sequelae The degree of rotational displacement however is lacking in their report The late effect of rotational displacement after femur shaft fractures is discussed by Müller (1967)

By roentgenological appraisal of the fracture itself Neer et al (1957) claim that some spontaneous correction of the rotational displacement may be anticipated in children It is usually claimed that spontaneous correction of the rotational displacement is non existent in adults Operative correction may then be necessary to eliminate pain and if possible to prevent late disability The rotational displacement can and should be calculated

The trigonometric roentgenological method of measuring the ante-version angle (Rippstein 1955) should be accurate enough for the pur pose of the present study—even if the error of calculation (mostly systematic) reported by Brattstrom (1962) is not taken into account The method required only one roentgen film for the qualitative evalua tion of the rotational displacement (see Figure 2 b) Two films were sufficient for the calculation of the exact degree of displacement and several other data of the hip joints The methods of Normann (1965) and Edholm (1966) required more roentgen films and are not consid ered so convenient for routine work

The conversion formulae in Rippstein s paper (1955) contain some grave typographical errors The conversion table in the same report according to Grote (1964) also contains small typographical errors These have been reprinted by Müller (1957)

External rotational displacement was most often found in our cases This is in agreement with the findings of Weigert et al (1968) They claim that this is due to the internal rotational effect of the iliopsoas muscle on the proximal fragment in the flexed hip during the osteo-synthesis

A torsional load is naturally less well tolerated than a bending one by an osteosynthesis done with the Küntscher clover leaf type nail

(Allen et al 1968) Some authors *therefore claim that rotational dis*placement may develop postoperatively before the fracture is healed This *may* be the cause in two of our patients with comminuted fractures

However it seems unlikely that rotational displacement may develop postoperatively when a stable osteosynthesis is achieved It is therefore essential that the rotational displacement also be reduced and roentgenologically controlled before the operation is completed—even if the osteosynthesis is done by open technique

SUMMARY

The preference for percutaneous versus open intramedullary osteosynthesis of femur shaft fractures entailed the evaluation of a trigonometric roentgenological method for the calculation of any uncorrected rotational displacement

The roentgenological method was considered accurate enough for this purpose In the small selected group of patients used for the evaluation of the method a rotational displacement mostly less than 10 was found in the healed fractures One patient only was handicapped due to an unreduced external displacement of 25 The advantages and the difficulties of the percutaneous intramedullary osteosynthesis are mentioned

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EFFECT OF TRANEXAMIC ACID (CYKLOKAPRON®) ON THE SYNTHESIS OF CHONDROITIN SULPHATE AND THE CONTENT OF HEXOSAMINE IN THE SAME FRACTION ON NORMAL AND DEGENERATED JOINT CARTILAGE IN THE RABBIT

HANS TELHAG

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ε aminocaproic acid (EACA) is a potent inhibitor of proteolytic enzymes (Alkjaersig et al 1959 Ali 1964 Weissmann & Spilberg 1968 Aoike et al 1969) EACA is demonstrable in articular capsules and synovia for up to 16 hours after intravenous injection (Ahlberg 1970)

Trans 4-amino methyl cyclohexane carboxylic acid tranexamic acid (AMCA) is a much stronger inhibitor of the activation of plasminogen *in vitro* than EACA (Nakahara et al 1966) These two inhibitors have been used in the treatment of rheumatoid arthritis and osteoarthritis with an apparently good effect (Nakahara et al 1966 Aoike et al 1969)

A good correlation has also been claimed (Whitehouse & Bostrom 1961) between the anti rheumatic effect of a drug and its ability to inhibit the biosynthesis of mucopolysaccharide sulphates in articular cartilage

AMCA (Cyklokapron supplied by AB Kabi Stockholm Sweden) has a strong inhibiting effect on the conversion of plasminogen to plasmin

The purpose of the present investigation was to assess the effect of AMCA on the synthesis of chondroitin sulphate and the content of hexosamine in the same fraction on normal and degenerated articular cartilage

MATERIAL AND METHODS

Five full grown rabbits (Group I) weighing 2 1 to 2 4 kg (mean 2 3 kg) were used One of the knee joints was operated upon according to a method (Hulth et al 1970) for making the knee joint unstable The other knee joint served as a control The animals were killed 3 months later Four hours before sacrifice 20 μCi ^{35}S as $Na_2{}^{35}SO_4$ (Radiochemical Center Amersham aqueous solution carrier free) was injected intra articularly into both knees

Another group (II) consisting of 10 full grown rabbits weighing 3 0 to 4 4 kg (mean 3 7 kg) were operated upon with the same method The unoperated knee served as a control From the first postoperative day the animals were given 0 5 g Cyklokapron a day by mouth 5 days a week throughout the experimental period The Cyklokapron tablet was grasped with curved forceps and placed on the posterior part of the tongue to elicit the swallowing reflex One of the animals offered difficulties and was therefore excluded from the material

After 3 months the animals were sacrificed by intravenous injection of a lethal dose of Nembutal 20 μCi ^{3} S was injected intra articularly into both knees of the animals 4 hours before they were killed Immediately after the animals had been killed the articular cartilage was dissected from the tibial and femoral con dyles of both knee joints The cartilage was removed as carefully as possible with a knife care being taken not to include other tissue The cartilage was immediately placed in acetone and dehydrated for a week, during which time the acetone was changed 3 times The preparation was then weighed (dry weight)

Glycosaminoglycans were extracted from the cartilage by digestion with papain in a phosphate buffer containing cysteine and disodium ethylene diamine tetra acetic acid as recommended by Scott (1960) but with a minor modification according to Hjertquist (1964) Chondroitin sulphate was precipitated from the digested sub stance by excess of cetylpyridine chloride (cpc) as a water insoluble cetylpyridin complex (Scott 1960) The hexosamine content of isolated polysaccharide fractions was determined by the Elson and Morgan reaction as modified by Blix (1948) and Antonopoulos et al (1964) Samples were hydrolysed in 6 N HCl for 8 h on a boiling water bath with subsequent removal of the HCl *in vacuo* in a desiccator over sodium hydroxide pellets Determination of radioactivity was made in a Packard Tri Carb liquid scintillation spectrometer (Packard Instr Company Inc) Each mg of the samples was diluted in 0 5 ml distilled water To 0 5 ml of this solution was added 3 5 ml distilled water and 5 ml of Instagel

RESULTS

In Group I the amount of hexosamine precipitated as chondroitin sulphate cpc complex per amount of tissue was significantly decreased in the degenerated cartilage (Table 1) The synthesis of chondroitin sulphate per amount of hexosamine was significantly increased in the operated joints

In Group II the amount of hexosamine in articular cartilage on the operated side did not differ from that on the control side The synthesis

of chondroitin sulphate was increased in the degenerated articular cartilage but the difference was not significant (Table 2)

Table 1 Concentration of hexosamines (hex am) and synthesis of chondroitin sulphate (ch.s) in untreated group (I)

Cartilage	γ hex am /mg	cpm ch s /mg	cpm ch.s /mg hex am
Controls	16 35 ± 1 66	122 5 ± 28 9	7 96 ± 1 92
Degenerated	9 [illegible]0 ± 0 [illegible]2	150 8 ± 41 4	17 14 ± 2 63
	0[illegible]>p> 01	6>p> 5	05>p> 01

Table 2 Concentration of hexasamines and synthesis of chondroitin sulphate in group treated with Cyklokapron (II)

Cartilage	γ hex.am /mg	cpm ch s /mg	cpm ch s /mg hex am
Controls	28 12 ± 1 91	1 74 ± 0 90	0 07 ± 0 03
Degenerated	31 22 ± 1 72	4 48 ± 1 74	0 16 ± 0 07
	3>p> 2	2>p> 1	3>p> 2

Table 3 Concentration of hexosamines and synthesis of chondroitin sulphate in control joints (left) in treated and untreated groups

Cartilage	γ hex am /mg	cpm ch s /mg	cpm ch s /mg hex am
Untreated	16 35 ± 1 66	122 5 ± 28 9	7 96 ± 1 92
Treated	28 12 ± 1 91	1 74 ± 0 90	0 07 ± 0 03
	01>p> 001	p> 001	p> 001

Table 4 Concentration of hexosamines and synthesis of chondroitin sulphate in operated joints (right) in treated and untreated groups

Cartilage	γ hex am /mg	cpm ch s /mg	cpm ch s /mg hex am
Untreated (I)	9 [illegible]0 ± 0 72	150 8 ± 41 4	17 14 ± 2 63
Treated (II)	31 22 ± 1 72	4 48 ± 1 74	0 16 ± 0 07
	p> 001	p> 001	p> 001

In the cartilage of the operated (Table 4) as well as of the unoperated knee (Table 3) the amount of hexosamine was significantly larger and the synthesis of chondroitin sulphate was significantly decreased in the group treated with Cyklokapron and regarding to the synthesis

of chondroitin sulphate both in relation to the amount of tissue and to the amount of hexosamine

DISCUSSION

Experimental degenerative changes can be induced in articular cartilage by various procedures such as compression of the articular surfaces (Salter & Field 1960 Crelin & Southwick 1964 Ginsberg et al 1969) or incisions of the articular cartilage (Carlson 1957) but such methods often produce a rather rapid degeneration of the articular cartilage In the method used in the present investigation relatively slow progressive degeneration of the articular cartilage was induced by the instability of the knee joint in full grown rabbits The degenerative changes produced resemble those seen in human osteoarthritis according to Collins (1949)

In conditions produced by proteolytic enzymes such as streptolysin S and in hypervitaminosis A the lysosomal membranes become labile and the cartilage matrix is broken down Certain drugs such as steroids acetylsalicylic acid and other antiphlogistic preparations used in the treatment of joint diseases act upon the function or diminish the release of substances from the lysosomes (Weissmann 1966)

Weissmann & Spilberg (1968) put forward a theory according to which protease in the lysosomes of the chondrocytes can break down cartilage matrix by acting upon the protein polysaccharide complex

In an *in vitro* investigation of bovine nasal cartilage the same authors have showed that EACA has a retarding effect on the breakdown of cartilaginous matrix It is not known with certainty whether lysosomes play any role in the aetiology or pathogenesis of osteoarthritis

Earlier studies by other investigators have shown a decrease in the hexosamine in degenerated cartilage (Matthews 1953 Ginsberg et al 1969 Mankin & Lippiello 1970 Bjelle et al 1972 Hjertquist & Lemperg 1972) Such a decrease was also found in the present study Articular cartilage is capable of a certain regeneration as judged from increased DNA synthesis which has been shown in degenerative joint diseases in man and in animals (Mankin & Lippiello 1970 Hulth et al 1972 Telhag 1972 Telhag & Gudmundson 1972) This increased synthesis is accompanied by an increased synthesis of glycosaminoglycans (Collins & McElligott 1960 Bollet 1969 Mankin & Lippiello 1970) In the present investigation the synthesis of chondroitin sulphate was found to be increased and this too must be regarded as a sign of regeneration of the cartilage

Cyklokapron was used in a daily dose corresponding to on the average 140 mg/kg body weight This dose slightly exceeds the maximal dose recommended for humans which is about 120 mg/kg body weight (Nilsson & Rybo 1967)

No significant differences in amount of hexosamine or synthesis of chondroitin sulphate were found between the operated and non operated knees in the group treated with Cyklokapron This may perhaps be explained by the assumption that Cyklokapron inhibits the activation of plasminogen to plasmin and/or by stabilizing the lysosomal membranes of the chondrocytes and thereby prevents the escape of enzymes and consequent breakdown of the ground substance

The present investigation showed that the amount of hexosamine was significantly larger in the group treated with Cyklokapron than in the untreated group In addition the synthesis of chondroitin sulphate was markedly reduced in the treated group The reason why the amounts of hexosamine were larger might be the same as that reported above If so it would mean elimination of the factor possibly stimulating the synthesis of chondroitin sulphate in degenerative joint disease

SUMMARY

Full grown rabbits were used One knee was operated upon to produce degenerative joint disease One group of animals was given AMCA by mouth The findings showed that AMCA markedly reduces the synthesis of chondroitin sulphate and increases the amount of hexosamine in this fraction in the articular cartilage of joints with and without degenerative changes

This suggests that the preparation prevents the degradation of the cartilage matrix either by preventing the activation of plasminogen to plasmin and/or by stabilizing the lysosomal membranes of the chondrocytes and is therefore apparently of value in the treatment of degenerative joint diseases

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COMPRESSION PLATING EXPERIMENTAL STUDY OF THE EFFECT ON BONE FORMATION RATES

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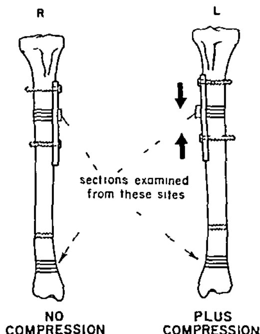
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The use of compression plates in the treatment of certain fractures of long bones and in the treatment of some cases of non union is clearly beneficial (Anderson 1965 Muller et al 1965) The benefits of compression plating may be related to (1) enhanced apposition (2) increased stability (3) increased new bone formation or a combination of these Many clinical examples illustrate increased bone formation resulting from increased stress such as the hypertrophy of a fibula grafted to replace a portion of a tibia or humerus in a young patient Eighty years ago Wolff (1892) published examples of cortical hypertrophy on the concave or compression side of malunited tibias Saville & Smith (1966) showed that increased load led to increased skeletal mass in the hind limbs of quadripeds which were made bipedal Chamay & Tschantz (1972) found in adult dogs increased bone formation in the ulna subjected to increased dynamic stress Schenk & Willenegger (1964) showed that the skeletal renewal rate was markedly increased underneath a compression plate applied to fix an osteotomy in the dog s radius compared to the rate in the intact control radius The present study was undertaken to determine if the stimulus to new bone formation following application of a compression plate was in fact caused by the compression

METHODS AND MATERIALS

To study the effect on skeletal renewal of the application of a compression plate without introducing the confusing and variable features of fracture repair compression plates were applied to intact bones of adult mongrel dogs (Figure 1) The plates were a miniature version of the A O compression equipment used in man Maturity of the dogs was established by roentgen evidence of complete closure of

Figure 1 Drawing of the application of compression plate to the intact right and left tibias of mature dogs Compression was added to the plate on the left tibia but not on the right



the epiphyseal plates at the knee elbow and shoulder All dogs had a two week period of conditioning in our animal farm prior to starting the study

Bone formation rates were assessed by using the long duration dual color coded tetracycline technique (Harris et al 1968) Two specific control values were essential for the accurate interpretation of the effect on bone formation rates of the compression from the compression plate First the level of bone formation prior to the application of the plate was required Daily administration of oxytetracycline (65 mg/kg/d) provided a label of all new bone deposited throughout the skeleton during the 12 weeks prior to application of the plates Data regarding the bone formation rate following plate application were obtained from intravital labelling of the skeleton with daily administration of demethylchlortetracycline (40 mg/kg/d) for the 12 weeks after surgery

Secondly knowledge of the effect of simply applying the plate without compression was required. This was obtained by applying the compression plates plus compression to the intact left tibia and applying identical plates to the right tibias in the identical manner but without adding the compression

An additional phase of this study examined the influence of distraction on bone formation rates by employing the identical experimental design except for the substitution of distraction plates for the compression plates

The plates were applied subperiosteally on the anterolateral surface of the tibia Both plates were applied during the same anaesthesia Particular care was taken to apply the plates to homotypic sites in each tibia. In the compression series compression forces, ranging from 24–55 inch pounds at the time of plate application were applied to the compression device using a torque wrench In the distraction

series the distraction forces ranged from 12 to 22 inch pounds at the time of plate application as measured by a torque wrench The dogs were ambulatory without a limp the day following surgery

After killing the dogs blocks of bone were obtained from the areas of the tibias underneath the plates and from the distal portion of the tibial diaphyseal regions away from the screw hole used to fix the compression or distraction device From these blocks undemineralized sections were cut on a Gillings Hamco Bone Sectioning machine and ground by hand to a thickness of 50 micra These sections were studied under ultra violet illumination using a grid-counting technique to determine the total amount of bone present the porosity the amount of bone deposited during the control period and the amount of bone deposited during the first 12 weeks after application of the plate

RESULTS

Table 1 shows the results in Dog 3 an animal which had plates applied to both tibias but with compression force added only to the plate on the left tibia The figures are given in the annual rate of new bone formation expressed as a percentage of total bone present During the control period the formation rates in right and left tibia are equal and low The application of the plate to the right tibia produced a massive increase in intracortical bone formation No significant additional stimulus to bone formation occurred on the left tibia under the plate which also had compression added

Table 2 gives the data from all four dogs which had compression plates The application of a plate produced a massive acceleration of skeletal renewal but the application of compression did not augment this rise

Table 3 shows the result in Dog 12 which had distraction plates applied to each tibia but a distraction force added only to the plate on

Table 1 Bone formation rates in intact bone under the influence of a plate plus compression and a plate without compression

A compression plate plus compression was applied to the intact left tibia An identical plate was applied to the right tibia without adding the compression Bone formation rates are given as per cent new bone formation per year

DOG 3		
	Bone formation rates	
	Right tibia	Left tibia
Control period	1 6	1 7
Experimental period	40	47

Table 2 Bone formation rates in four dogs treated with compression plates
A plate plus compression was applied to the intact left tibia An identical plate but without compression was applied to the intact right tibia. Bone formation rates are in per cent new bone formation per year

Dog No	Side	Control period	Experimental period	
3	L	1.7	compression	47
	R	1.6	plate alone	40
4	L	2.6	compression	69
	R	1.3	plate alone	62
6	L	6.8	compression	51
	R	9.8	plate alone	71
14	L	2.1	compression	90
	R	1.3	plate alone	56

the left tibia The application of the plate was a massive stimulus to the bone formation rate but the added distraction force neither augmented nor reduced this stimulus

Table 4 shows the results in four dogs with distraction plates No significant effect of the distraction is apparent on the rate of skeletal renewal

Since porosity could not be measured for the baseline time period prior to plate application in these animals the comparison of the porosity figures before and after plate application cannot be made However certain observations can be made regarding porosity In the experiments using compression plates and in those using distraction plates porosity under the plates showed a tendency to be greater than porosity values from the same areas in 11 control dogs However at 12 weeks after plate application these differences were not significant

Table 3 Bone formation rates in intact bone under the influence of a plate plus distraction and a plate without distraction
A distraction plate plus distraction was applied to the intact left tibia An identical plate was applied to the right tibia but distraction was not added Bone formation rates are given as per cent new bone formation per year

DOG 12		
	Bone formation rates	
	Right tibia	Left tibia
Control period	3.0	2.9
Experimental period	63	69

Table 4 Bone formation rates in four dogs treated with distraction plates A plate plus distraction was applied to the intact left tibia. An identical plate but without distraction was applied to the intact right tibia Bone formation rates are expressed as per cent new bone formation per year

Dog No	Side	Control period	Experimental period	
5	L	21	distraction	35
	R	16	plate alone	30
7	L	25	distraction	111
	R	19	plate alone	65
12	L	2 9	distraction	69
	R	3 0	plate alone	63
13	L	1 4	distraction	41
	R	0 8	plate alone	51

No difference in porosity was discernible between the bone with a compression plate plus compression and that with an identical plate without compression No significant difference existed between those bones under distraction plates with or without a distraction force added No difference existed between the effect of distraction plates and compression plates

DISCUSSION

The massive stimulus to bone formation under a compression plate is due to the application of the plate and not to the application of compression Contrary to our expectation the effect on bone formation rates of applying a plate with distraction is also dominated by the influence of the plate application and is not altered by applying distraction

Perren et al (1969) have shown that the compression force generated by application of a compression plate to an intact bone persists as long as 12 weeks but gradually declines Our experiments studied the effect of a progressively decreasing static load on bone and should not be interpreted as describing the effects of dynamic or intermittent loading of bone Also small responses of bone to compression might not be appreciated in our study because if present they would be overshadowed by the marked response of bone to the application of a plate alone

A statistically significant rise in porosity was not seen even under the distraction plate at 12 weeks Studies such as those of Uhthoff &

Dubuc (1971) show that such a rise in porosity occurs in experiments of longer duration

SUMMARY

The effect on bone formation of applying compression via a compression plate was studied in four adult dogs Bone formation rates were determined using the dual color coded long duration tetracycline labelling method To study this effect independent of the confusing elements introduced by fracture healing the compression plates were applied to the intact bones without fracture or osteotomy Two controls were used The first was the rate of bone formation prior to plate application The second was the effect of the plate alone without compression Using an identical surgical procedure a compresion plate plus compression was applied to the left tibia and an identical plate was applied to the right tibia without adding the compression force

A similar experiment was carried out in four other adult dogs except that distraction was applied to the plate on the right tibia

During the 12 weeks following the application of a plate and screws to the intact tibia of the adult dog a marked stimulus to new bone formation occurred The application of compression did not add to this increase Distraction neither enhanced nor reduced this increase Porosity tended to rise under all plates with or without compression or distraction but by 12 weeks had not reached a level of significant difference

The major stimulus to new bone formation following compression plate application is the application of the plate and screws alone Added compression has no discernible effect on this stimulus

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TWENTY NINE CASES OF BACTERIAL ARTHRITIS

A prospective study

LARS LIDGREN & LARS LINDBERG

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Since the advent of antibiotics in the 1940s the clinical course of bacterial arthritis has changed in various respect The acute forms have become less common and subacute forms more so Bacterial arthritis has become less common in children and more common in adults The disease also appears to have changed from a bacteriological point of view These changes which have received but little attention by orthopaedic surgeons require continual analysis of clinical series of bacterial arthritis if the principles of diagnosis and treatment are to keep pace with these changes Such analyses are important above all because the diagnosis bacterial arthritis must be made early and treatment started without delay if permanent joint changes are to be avoided (Clawson & Dunn 1967 Schmid & Parker 1969 Kelly et al 1970)

This paper reports an analysis of a 5 year series of bacterial arthritis treated at a department of orthopaedic surgery with special reference to the clinical picture the interval between the onset of infection and the beginning of treatment the results of treatment and any predisposing factors

MATERIAL AND METHODS

Clinical series

During the years 1963–1967 a prospective investigation was being carried out on all patients with orthopaedic infections at the Department of Orthopaedic Surgery Malmo General Hospital This material whose composition has previously been described (Lidgren & Lindberg 1972) included 28 patients with bacterial arthritis These constituted the present series One patient had arthritis first on one joint and later of the contralateral joint The affection on each side was regarded as a separate case The number of cases with arthritis was thus 29

The town of Malmo (241 7.8 inhabitants on Dec 31 1963 and 254 338 inhabitants

on Dec 31 1967) lends itself well to investigations of this type because the above mentioned hospital is the only hospital for somatic diseases in the town (Lidgren & Lindberg 1972)

Since no patients with bacterial arthritis were admitted to the Department of Paediatrics during the period covered by the investigation all cases of bacterial arthritis in the town had presumably been admitted to the Department of Orthopaedic Surgery

Diagnosis and treatment

Joint fluid was invariably aspirated for analysis and for bacterial culture including sensitivity tests Recordings were made of the temperature and samples were obtained for measurements of E S R and determination of the antistaphylolysis titer (ASTA) and C reactive proteins (CRP) In some cases also blood faeces or urine were cultured for bacteria All patients were examined roentgenologically At re examination of the roentgenograms a search was also made for signs of chondrocalcinosis

In 4 ca es bacterial culture was negative and in one case no culture was performed but bacterial arthritis was diagnosed on the basis of the clinical course raised E S R positive serologic findings findings in the aspirated synovial fluid and prompt response to antibiotics

The principles of treatment were as follows As soon as bacterial arthritis was suspected samples were obtained for bacterial culture after which antibiotic therapy was started immediately As soon as the results of culture end sensitivity test were obtained antibiotic therapy was modified if necessary In most cases the affected joints were immobilised with traction or a splint in the acute stage and joint fluid was repeatedly aspirated

Review

In 1971 information was obtained from all the patients except one who had moved to an unknown address 18 of the 27 patients were examined clinically and roentgenologically The clinical examination was done according to *Joint motion Method of measuring and recording* (1965) Blood samples were obtained for determination of ASTA CRP and E S R Five patients gave the desired information by letter or by telephone Four of the patients had died but some information about the course of the arthritis was obtained in other ways

The interval between the patient s discharge from hospital and the review was on the average 5 9 year

RESULTS

The patients (14 men and 14 women) had a mean age of 49 years at onset (range 11 to 74 years) Ten of the cases of arthritis were of haematogenous origin and 11 of postoperative 8 were due to injection into the joint (3 arthrographies and 5 injections of steroids) Of the joints 16 were knees 7 hips 4 elbows and 2 shoulder joints Possibly

predisposing local factors were rheumatoid arthritis in 7 cases, arthrosis in 2, earlier fracture in 2, earlier trauma without fracture in 1 and radiation reaction in 1. In 3 cases chronic pain of unknown cause without associated roentgen changes was the indication for the injection with steroids, which resulted in infection.

Nineteen cases of arthritis were due to Staphylococcus aureus (positive culture of synovial fluid in 17, of the blood in 1, and of the faeces in 1), which in 12 of the cases was resistant to penicillin. One case was due to Escherichia coli, 1 to diphtheroids, 1 to enterococci, 1 to βeta streptococci and 1 to Serratia marcenscens. In 4 cases culture was negative and in one case culture was not done. In one of the cases with negative culture gonococcal complement fixation was positive. In 3 cases the bacteria were resistant to the antibiotics used before the bacteriologist's report had been obtained.

Clinical picture

None of the patients exhibited a picture of sepsis or prostration in any stage of the infection, nor was any correlation demonstrable between the clinical picture, including ASTA, CRP, ESR and temperature, at onset and the findings at the review.

The review

At the review the patients were divided into 3 groups.

Group I. Cases where the infection had not caused any demonstrable joint change (11).

Group II. Cases where the infection had caused permanent joint injury (11).

Group III. Cases where the effect of the infection could not be estimated because the joint had already been damaged to a varying extent before the infection and it was not possible to decide whether the joint had become worse (6).

The mean age at onset in Group I was 35 years, in Group II 58 years and in Group III 60 years. Possibly predisposing factors were noted in 3 of the cases in Group I, in 8 of Group II and in 5 in Group III. The interval between the onset of symptoms and the beginning of treatment varied widely but was on the average shorter for the patients in Group I, where it was 6 days, compared with 23 days in Group II

DISCUSSION

Haematogenous bacterial arthritis was formerly regarded as being most common in children In recent years however there appears to have been a shift towards higher ages so that the disease is now equally common in adults (Kelly et al 1970 Lidgren & Lindberg 1972) This is clear also from the present study It is of special interest that during the period covered by the investigation no cases of bacterial arthritis had been treated at the children s hospital

The joints most often involved by bacterial arthritis were the knee and the hip an observation that agreed well with what has been found in previous investigations (Kelly et al 1970)

According to the literature predisposing factors are rheumatoid arthritis arthrosis poor general condition systemic treatment with steroids or cytostatics paraplegia earlier operations in or trauma of the joint (Ward et al 1960 Bulmer 1966 Clawson & Dunn 1967 Schmid & Parker 1969 Kelly et al 1970 Lidgren 1972) In the present investigation 7 of the patients had rheumatoid arthritis Earlier trauma operation or arthrosis were also noted In 12 cases no predisposing factor was known

In 8 cases the infection had occurred after injection into the joint The importance of strict asepsis at injections into a joint cannot be emphasised enough Though arthritis may occur after injection of steroids (Gedda & Juhlin 1959 Tondreau et al 1959 Ward et al 1960 Camelot & Lamoril 1964) the risk of such a complication following joint puncture performed lege artis is fairly low These 8 cases were probably the only ones that occurred in Malmo during the 5 year period in which punctures had surely been performed in a vast number of joints

None of our patients exhibited a picture of sepsis or poor general condition owing to the infection This agrees with the observation made by other authors during the last decades The formerly common acute onset has tended to become subacute

Most of the cases of arthritis were due to Staphylococcus aureus which was resistant to penicillin in 12 of 19 cases Staphylococcus aureus has also been erported in the literature as causal bacteria in more than half of the cases (Ward et al 1960 Clawson & Dunn 1967 Griffin 1967 Kelly et al 1970) Exceptions were children between 1/2 year and 2 years where Haemophilus influenza is most common (Nelson & Koontz 1966) Arthritis due to a number of other sorts of bacteria such as streptococci pneumococci meningococci salmonella proteus pseu

domonas and clebsiella are on record (Ward et al 1960 Bulmer 1966 Nelson & Koontz 1966 Clawson & Dunn 1967 Kelly et al 1970) Serratia marcescens was the causing organism in one of the cases Only one case of arthritis caused by this microorganism could be traced in the literature (Atlas & Belding 1968) and a further unpublished case of osteitis has been observed by the authors

Which antibiotics should be given in the acute stage until the results of culture and susceptibility tests have become available? In Scandinavia the patients should at present be treated with a combination of isoxazolyl penicillin and a bactericidal preferably synergistic broad spectrum antibiotic Isoxazolylpenicillin inhibits Staph aureus even if they are resistant to "common penicillin and the broad spectrum antibiotic inhibits a large spectrum of other types of bacteria not susceptible to penicillin In recent years the authors have used cloxacillin combined with ampicillin or gentamycin (Because of the risk for serious side effects the dose of gentamycin has always been decided upon after consulation with the Department of Infectious Disease) The choice of this combination is based on results of an investigation of the bacteriology of orthopaedic infections treated during the last 15 years at the departments of orthopaedic surgery where the authors have served This investigation will be published in a later article

Early antibiotic therapy is very important for the prognosis In the acute case antibiotic therapy must be started within 1–2 days if permanent joint injury is to be avoided (Clawson & Dunn 1967 Schmid & Parker 1969 Kelly et al 1970) This has also been confirmed experimentally (Bardenheier et al 1966 Orchard & Stamp 1968) In the present material most of the cases were subacute subchronic and the interval between the onset of symptoms and treatment was on the average shorter for patients who were symptom free at the review than among those in whom the infection had caused permanent joint injury The 11 patients in whom the infection had not produced any permanent joint injury were also younger than the 10 patients in whom the infection caused permanent joint destruction In the former group only 3 of the patients had predisposing factors compared with 7 in the latter group The composition of the material however does not allow statistical analysis

In recent series joint destruction is often reported in about half of these cases Kelly et al (1970) described 78 cases with bacterial arthritis from the Mayo Clinic Twelve of these patients died as a direct consequence of their infection and only 12 patients had no joint

destruction at a review 2–10 years after the infection was cured In the present investigation more than one third of the patients were symptom free at the review and none of the patients died from their infection

The relatively good end results obtained in the present series does not mean a better or different therapy but can probably be explained by the organisation of the health service in Malmo Since bacterial arthritis is a very painful disease most of the patients had sought medical advice early and most of them had come straight to the Department of Orthopaedic Surgery Others who had sought advice elsewhere had been referred there while their disease was still in an early stage At the Department of Orthopaedics where patients are also admitted at night the treatment of arthritis was standardised in the above mentioned way during the present investigation and both the surgeons and the personnel had received detailed instructions as to how patients with bacterial arthritis should be cared for The patients therefore received adequate therapy in an early stage of the disease which explains the good results achieved

SUMMARY

All the 29 cases of bacterial arthritis diagnosed in 1963–1967 in a town of about 250 000 inhabitants were studied prospectively with special reference to the clinical picture the interval between the onset of infection and the beginning of treatment the result of treatment and any predisposing factor As expected from some previous investigations of bacterial arthritis it was found that the clinical picture of the infection had changed in several respects in the course of the last few years The mean age of patients with haematogenous arthritis had risen bacterial arthritis is now more common in adults than in infants *the acute onset of bacterial arthritis is now less common* and the subacute form more common Better results were obtained in patients in whom treatment was started soon after onset Predisposing factors and the reasons why the results were relatively good are analysed

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OSTEOARTHRITIS OF THE THIRD METACARPO PHALANGEAL JOINT

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Osteoarthritis of the hand usually involves several joints unless it develops as a consequence of isolated trauma to one single joint The proximal and distal interphalangeal joints are the most commonly affected Metacarpo phalangeal joints seldom participate in a generalised degenerative osteoarthritis and almost never in its initial stages The carpal joints do participate occasionally in the process among them the most common and characteristic location is the carpometacarpal joint of the thumb

The present report describes a small series of seven patients in whom clinical and radiological signs have shown an involvement of the metacarpo phalangeal joints The most prominent feature brought out by this series was the initial and progressive involvement of the third metacarpo phalangeal joint In all cases clinical signs have been related predominantly to the third metacarpo phalangeal joint whereas the adjacent joints even if radiologically affected have remained clinically silent (Case 1)

The present report will deal particularly with *common diagnostic problems* treatment will not be discussed in detail

CASE REPORTS

Case 1 M B a 57 year old housewife was first seen in our clinic in February 1968 with a history of pain and swelling on her right hand Pain and discomfort were more pronounced when she performed prolonged or heavy manual work There was no history of trauma and no other arthritic pain The patient was right handed She was treated symptomatically but the pain increased Two months before admission she had a course of X ray therapy without improvement When examined for the first time she had a pronounced fusiform swelling over the third knuckle with local tenderness and limitation of motion of the third metacarpo phalangeal joint The roentgenogram showed narrowing of the joint space and changes of the metacarpal head with irregular contour and osteophytes projecting into the soft

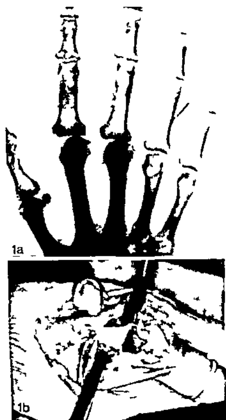


Figure 1 A The third metacarpo phalangeal joint is narrow and irregular Note the particular destruction of the ulnar side B The metacarpal head has been excised Note that most of its articular cartilage has been destroyed

tissues (Figure 1 A) There was no osteoporosis of the bones of the affected hand the sedimentation rate was normal and the latex fixation test was negative Because of progressive symptoms she was admitted to the hospital in March, 1970 On admission the third metacarbo phalangeal joint was found to be moderately swollen and painful There was a flexion contracture of about 20 and range of motion was limited to 50 of active flexion Repeated roentgenographic examination showed increased sclerosis of the subchondral bone and more deformity of the head of the third metacarpal than on previous films It is to be noted that although slight irregularity of the articular surface of the second metacarpo phalangeal joint could be interpreted as a beginning osteoarthritis there were no clinical signs related to that joint The patient underwent a silicone type arthroplastry of the third metacarpo phalangeal joint The excised metacarpal head showed a large area of loss of articular cartilage (Figure 1 B) underlying sclerosis and multiple osteophyte formation She returned to her household activities about six weeks after surgery and gradually regained her working capacity The last examination about two years after operation revealed an improved range of motion between zero and 60 and a strong painless grip The radiograms showed no further progression of osteoarthritis among the other joints of the hand





Figure 2 A Almost missing joint space and advanced structural changes of the metacarpal head B Showing degenerative changes of the cartilage with vertical and tangential fibrilation C Showing focal sclerosis of the subchondral bone and loss of the superficial layers of the cartilage (hematoxylin–eosin × 40)

Case 2 Sh J a 64 year old farmer was seen at the hand clinic complaining of pain in his right hand for more than one year There was no known injury The symptoms were moderate and had increased slowly over the preceding year The patient was right handed He had been treated by paraffin baths ultrasound salicylates indomethacin and exercises with only transient improvement At the time of admission his condition had worsened and it was seriously interfering with his usual activities The examination revealed an oval tumor like swelling over the third knuckle and a very restricted painful motion of the metacarpo phalangeal joint The range of flexion was from 10 to 40 in comparison with minus 10 to 90 on the left Radiological examination showed a narrow almost missing joint space irregularity of the metacarpal head and osteophytes projecting into the soft tissue from the joint margins (Figure 2 A) There was no real flattening or fragmentation of the metacarpal head There were no changes related to the other metacarpo phalangeal joints The sedimentation rate was normal and the latex fixation test was negative The patient was operated on and a silicone type arthroplasty was performed Histologically the resected metacarpal head showed large patchy areas of destroyed or degenerated articular cartilage and a concomitant sclerosing process in the underlying bone with cystic structural changes (Figure 2 B and C) Three weeks after the operation the patient was sent to physical treatment He returned to

his usual farm work few weeks later The last examination more than two years after surgery revealed no swelling improved and painless motion and increased strength.

The remaining five patients four men and one woman showed very similar changes concentrated over the third metacarpo phalangeal joint In none of them were there any signs clinical or roentgenographic, related to the other metacarpo phalangeal joints All patients were engaged in physical work. One of them was 46 years old the rest aged over 50 By the time of completing this study two patients were still under conservative treatment. All the others underwent resection arthro plasty of the third metacarpo phalangeal joint

DISCUSSION

This small series of seven patients is characterised clinically by a localised swelling and painful limitation of motion of the third meta carpo-phalangeal joint With one exception the process had affected patients in their sixth and seventh decades No systemic symptoms were found and laboratory examinations were all normal The differen tial diagnosis includes the so-called Dietrich s disease which has a similar location

Dietrich s disease described as an osseous aseptic necrosis of the head of the metacarpals is an extremely rare condition It has been reported mainly in the German literature and is characterised by solitary or multiple affections localised to all but the first metacarpal heads (Dietrich 1932 Friedl 1934 Bopp 1938 Carstam & Danielson 1966) Radiologically it shows fragmentation and flattening of the affected metacarpal head with shortening in total length Dietrich s disease has been reported in patients from 15 to 51 years Although the age at diagnosis may vary most cases develop during the first two decades Neither clinically nor radiologically does this condition con stitute a clear cut nosological entity The radiological characteristics of various cases described as Dietrich s disease had often very few in common thus provoking the question whether they should be in cluded in the same category (Kohler 1956)

The seven cases in our series were classified as osteoarthritis accord ing to their clinical courses and radiological findings Painful limita tion of motion and progressive narrowing of the joint space were the main findings common to all of them No real flattening or fragmenta tion of the metacarpal heads were noted Histological examination performed in four of the operated patients provided further support for this assumption

Neither in the ... of the cases reported here, nor in their clinical course were there any elements which could suggest the possible etiology of the process. Why should an osteoarthritis particularly affect the third metacarpo-phalangeal joint while the adjacent joints would be left undisturbed? Should the affection of the third metacarpo-phalangeal joint be considered an isolated location or as the beginning of a process which would eventually spread further and involve the other metacarpo-phalangeal joints? No definitive answer could be given to those questions. The problem of the initial involvement of the third metacarpo-phalangeal joint probably has something to do with the fact that the third knuckle is the most prominent one, and in this respect is exposed to injury more than the others. Trauma as a single external act of violence has not been established as a common feature in the reported series. However repeated micro-injuries possibly connected with the kind of life of a particular patient, or specific occupational requirements, could almost never be denied absolutely. More attention to this condition and further cumulation of details would probably offer the clue to better understanding of its pathomechanics.

SUMMARY

A series of seven cases showing isolated affections of the third metacarpo-phalangeal joint has been reported. The possible nature of these ... as well as problems of differential diagnosis have been briefly discussed.

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A CASE OF CARPAL TUNNEL SYNDROME ON THE BASIS OF AN ABNORMALLY LONG LUMBRICAL MUSCLE

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Accepted 19 1 73

The carpal tunnel syndrome is defined as sensory and motor symptoms from the median nerve according to its distribution area distal to the wrist joint (Rasmussen & Stougård 1969) The symptoms are caused by a compression of the nerve in its passage through the carpal tunnel The causes of this compression can according to Entin (1968) be divided into the following groups (1) diminution of the volume of the carpal tunnel (2) increase in the volume of the structures which together with the median nerve pass through the carpal tunnel (3) accompanying symptom in a systemic disease Included in the above mentioned groups (1) and (2) are the rare cases of carpal tunnel syndrome caused by anatomical variants

In our unit we have recently observed a case of a rare anatomical variant in connection with an operation for carpal tunnel syndrome

CASE HISTORY

A 31 year old worker who for six years had suffered from pains in the right wrist joint radiating down to the right hand and up the lower arm When admitted to hospital the patient complained of paraesthesiae in the entire right hand not especially limited to the median area and also of lack of strength in the right hand and lower arm On examination tenderness was observed over the right median nerve at the flexor retinaculum and also over the nerve in the lower arm There was furthermore clear diminution of strength in the wrist joint and elbow joint on the affected side An x ray of the forearm and hand showed nothing abnormal At operation an anatomical variant was discovered as the lumbrical muscle from the profundus tendon to the third finger arose more proximal than usual on the tendon (Figure 1)



Figure 1 The forceps are gripping the lumbrical muscle from the profundus tendon to the third finger The small artery forceps are located proximally on the radial side of the severed flexor retinaculum Between these can be seen the median nerve

When the hand was in a position of rest the origin lay proximal to the upper edge of the flexor retinaculum There was no visible compression of the median nerve but the above mentioned abnormality could cause compression of the nerve during exercise

DISCUSSION

In the literature only very few cases of carpal tunnel syndrome on the basis of anatomical variants have been described In Phalen s comprehensive material of 1966 relating to 654 patients operated for carpal tunnel syndrome none was found with the above mentioned aetiology This can as he states himself be due to the method of operation as most of these patients were operated on through a transverse incision in the palm and this gives a poor visual survey In the material of Rasmussen & Stougård (1969) is was found that among 91 operated cases only a single one was caused by an anatomical variant In this abnormally long muscle bellies to the sublimis tendons were found This variant has also been described by Tanzer (1959) Robbins (1963) and Bunnel (1964)

Only once before has an abnormally proximal origin of the lumbrical muscles been described as the cause of carpal tunnel syndrome (Touborg Jensen 1970)

SUMMARY

A case is reported of carpal tunnel syndrome due to an anatomical variant in the form of an abnormally proximal origin of a lumbrical muscle.

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FORTY EIGHT CASES OF CAPUT ULNAE SYNDROME TREATED BY SYNOVECTOMY AND RESECTION OF THE DISTAL END OF THE ULNA

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Resection of the distal end of the ulna was introduced in 1912 by Darrach as treatment of pain and reduced movement in the wrist caused by traumatic dislocation of the caput ulnae Resection of the caput ulnae was used by Smith Petersen in 1940 the time at which surgery was beginning to be employed in the treatment of rheumatoid arthritis (rh a) Smith-Petersen used it as part of arthrodesis and in later years the procedure has been used by Flatt (1963) Kessler & Vainio (1966) Straub & Ranawat (1969) together with Kessler & Hecht (1970) to make synovectomy of the wrist total

Rh a often attacks the wrist This consists of a radioulnar joint and a radiocarpal joint which are clearly separated by a septum The affection usually starts in the ulnar part with proliferative synovitis which causes laxity of the ligaments and a thinning of the capsule In addition a destruction of the triangular disc and of the styloid process is seen and gradually of the whole distal end of the caput ulnae with widening of the joint and dislocation of the caput ulnae

Rupture may occur as a result of involvement in depth or when the disease is primarily located to the ulnar extensor tendons This is presumably further enhanced by the attrition of the dislocated caput ulnae on the tendons during rotational movement

A characteristic picture based on the changes mentioned above occurs This has been thoroughly described by Bäckdahl in 1963 under the name caput ulnae syndrome The main clinical characteristics are (1) rotational pain weakness and limitation of movement in the wrist (2) the caput ulnae is dislocated and forms a dorsal prominence on the wrist (3) in a dorso ulnar position there is a tender soft fluctuating swelling (4) possibly extensor tendon rupture

Resection of the caput ulnae was carried out by Rasmussen & Snep-

pen in 1967 the indication was tenderness on rotation and limitation of movement It was also employed by Cracchiolo & Marmor in 1969 for the caput ulnae syndrome The object of the present work is to report the results of the procedure when the caput ulnae syndrome is used as the indication and thereby supplement the scanty literature available

MATERIAL AND METHODS

Forty patients with rh. a (according to the American Rheumatism Associations criteria) representing 48 cases of caput ulnae syndrome, were subjected to resection of the caput ulnae together with synovectomy 37 patients representing 45 operated wrists were examined at follow up the remaining 3 patients were dead at that time.

Twenty six of the patients examined at follow up were women The average age was 57 years (range 24–77 years) The average duration of the rh. a. was 9 years (range 1 33 years) with an average of 7 years for the wrist affection (range 0–23 years) The main complaints were pain on rotation, a limitation of rotational movement and a tender swelling to an extent that the function of the wrist was reduced in all the cases One patient had rupture of the tendon to the extensor pollicis longus preoperatively and 2 had extremely thin indicis proprius tendons None of the patients had rupture of the extensor carpi ulnaris, but the tendon in a number of patients was very thin Preoperative radiographic changes were seen only in the distal radioulnar joint of 15 wrists in the remainder there were also changes in the radiocarpal joint. Among the first mentioned 15 wrists the caput ulnae resection was supplemented in 4 cases by synovectomy in the radiocarpal joint. This also applied to 18 cases in the remaining 30 wrists All the patients had been carefully observed and treated medically in a department of physical medicine preoperatively

The procedure was carried out under general anesthesia. A longitudinal S-shaped incision was made above the distal end of the caput ulnae under tourniquet control. The lower 3–4 cm of the ulna together with the triangular disc were removed, and at the same time as much as possible of the proliferating synovial tissue The extensor tendons were inspected and cleansed of synovial tissue and placed in the anatomically correct position if they had slipped. A compression dressing was used for the first 24 hours and the day after operation intensive exercises were commenced.

RESULTS

The follow up examination was carried out from 4 to 100 months after the operation (mean 46 months) The pain on rotation was changed as shown in Table 1 Of the 5 wrists giving pain one was unchanged 3 were free from pain for periods while in the 5th case arthrodesis was carried out 2½ years after the operation owing to persisting pain on rotation and synovitis The wrist was then free from pain A swelling could not be seen in any of the radioulnar joints but 2 patients stated that it was present periodically The range of movement was changed

as shown in Tables 2 and 3 The improvement was evident in rotation particularly in supination In 21 cases the patient considered the grip strength to be reduced after the operation whereas the strength in the other cases remained unchanged Measurements using a Geigy balloon were in the main in agreement with these evaluations In no case was the loss of strength confined to the operated wrist During supination and pronation movement 16 patients were initially inconvenienced by a snapping sensation corresponding to the resected end of the ulna This sensation disappeared in all the cases within the course of the first year 33 patients found that the operation had resulted in the wrist being more useful and none found the function of the wrist reduced or the wrist unstable There was no postoperative rupture of a tendon

Table 1 Pain during rotation

Number of wrists	Pain present	Pain absent
Preoperative	45	0
Postoperative	5	40

Table 2 Supination (sup) and pronation (pro)

Degrees	Number of wrists preoperative sup	preoperative pro	postoperative sup	postoperative pro
90	17	17	34	32
89–45	10	16	8	10
44– 0	18	12	3	3
Total	45	45	45	45

Table 3 Volar (vol) and dorsal flexion (dor)

Degrees	Number of wrists preoperative vol	preoperative dor	postoperative vol	postoperative dor
45	6	13	7	12
44–20	18	15	21	17
19– 0	21	17	17	16
Total	45	45	45	45

Of the 15 wrists with preoperative x ray changes isolated to the distal radioulnar joint 2 were seen postoperatively to have affection of the radiocarpal joint both *cases occurred in patients on whom radial* synovectomy had not been performed In the remaining 30 joints further progressing in the radiocarpal joint was seen in 16 cases of these 5 occurred in the 18 wrists which had been subjected to radial synovectomy

DISCUSSION

The most characteristic finding is elimination of the rotational pain and an increase in rotational movement in other words an obviously favourable effect on the main symptoms of the patient Rasmussen & Sneppen (1967) and Cracchiolo & Marmor (1969) found corresponding *results in their materials which were of a similar size to that presented* here The 5 patients with persisting rotational pain did not differ from the others in sex age or duration of disease One of these patients had slight radiological changes preoperatively the other 4 patients had *severe destructive processes both in the radioulnar and the radiocarpal* joints At the follow up examination all 5 patients showed progress as evaluated by x ray examination

It appears that the procedure arrests the proliferation of the synovial tissue in the distal radioulnar joint which is again in agreement with the results of Cracchiolo & Marmor (1969) These authors found an increase in the strength in approximately 60 per cent of the patients No explanation of this discrepancy between the two materials can be given The stability of the wrist was good after the operation in all of the cases which is in keeping with the fact that the distal end of the ulna does not give support to the bones of the carpus Since a later arthrodesis is not excluded by the operation even severe changes in the joint will not be a contraindication to resection of the distal end of the ulna

It is reasonable to attempt the operation when caput ulnae syndrome occurs providing intensive physical and medical treatment has been attempted without successful results Since rotational pain and a reduction in rotational movement are the main factors inhibiting the use of the hand in such common everyday movements required for washing dressing turning the handle of a door etc a painful and badly functioning wrist will at the same time contribute to the inactivation of the adjacent joints

SUMMARY

Forty eight resections of the distal end of the ulna were carried out on 40 patients suffering from rheumatoid arthritis The indication for the procedure was primarily reduced movement and rotational pain in the wrist in connection with dorso ulnar swelling and dislocating of the caput ulnae All the patients had been subjected to conservative treatment preoperatively without satisfactory results 37 patients representing 45 operated wrists were examined at follow up The operation had had a favourable effect on the swelling rotational pain and rotational movement but no effect on the dorsal volar flexion and the strength was found to be unchanged or reduced No operative or postoperative complications occurred

ACKNOWLEDGEMENTS

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TWO PECULIAR CASES OF BONE DEFORMITY AFTER OSTEOSYNTHESIS

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Thanks to experience accumulated from innumerable operations with fixation of pins, plates and other appliances to living bone during the past 50 years (Venable & Stuck 1947, Leventhal 1951, Scales et al 1959, Hicks et al 1958, Laing et al 1959, Emneus et al 1960, 1965, Muller et al 1963), it is now possible to assess the effect of metal implants in the human body with reasonably good accuracy.

The human skeleton will accept almost any inert metal implant when used to stabilise bone temporarily, provided that there is no movement between the bone and the implant. Modern arthroplastic materials are accepted less well, though better than was anticipated 15 years ago.

This paper describes two almost identical cases with remarkable transformation of bone due to an implant.

CASE HISTORIES

Case 1. In December 1956 a 51 year old woman sustained a fracture of the right humerus. An osteosynthesis ad modum Kuntscher was performed, but January 1957 she fell again and the Kuntscher nail was bent. The fracture was reduced and the nail was straightened. In July 1957 a pseudarthrosis was evident. A new Kuntscher nail was inserted and bone grafting performed. External fixation was not employed.

The pseudarthrosis persisted, however, and in January 1959 the woman refused further treatment. She did light work at home until 1967, when she observed a large swelling of the distal part of the right upper arm. In February 1968 she sought advice at the Orthopaedic Department, Uddevalla, where examination showed an almost rigid elbow and a pseudarthrosis allowing almost 90° of movement. Distal to the pseudarthrosis X-rays revealed a transformation of the humerus to a cyst as big as an orange (Figure 1). In May 1968 she consented to



Figure 1 The appearance of the cystic deformed distal fragment 1967 ten years after the nailing

extraction of the nail but refused further operations as she had become accustomed to her unusual disability We also thought it unlikely that the humerus could be stabilised satisfactorily Biopsy of the pseudocyst had shown no evidence of malignant change She was reluctant to return for review but finally agreed to an X ray in 1971 by which time a considerable reduction in the size of the cyst had occurred (Figure 2)

Case 2 In June 1959 a 63-year-old woman sustained comminuted fractures of the right humerus and left femur Open reduction of the fractures was carried out with osteosynthesis ad modum Küntscher of the humerus and fixation of the femur with plate and screws By December 1959 it was clear that neither of the bones had united and a new Küntscher nail was inserted into the humerus and the plate and screws were removed from the femur and replaced by a Rush pin In March 1962 there was obvious pseudarthrosis of both humerus and femur On the humerus a new Küntscher nailing and bone grafting was

Figure 2 Same patient three years after extraction of the nail



Figure 3 The appearance of the pseudarthrosis 1963 three years after the fracture and one year after the last nailing

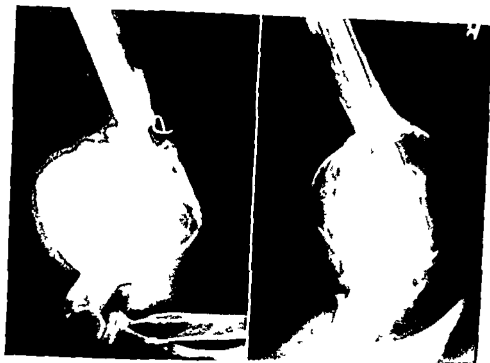


Figure 4 The cystic deformation of the distal fragment nine years after nailing

done (Figure 3) A thoraco-brachial plaster was applied for two months Unfortunately the fractures did not heal and in 1963 the patient declined further treatment She walked with two crutches

In March 1971 she came to our department because of a tumor in the distal right humerus (Figure 4) and the femoral pseudarthrosis was so disabling that she could no longer walk In September 1971 the femoral fracture was treated with compression osteosynthesis and is now healed Concerning humerus the only surgical procedure has been removal of the Küntscher nail (Figure 5)

In both these cases humeral mal union was followed by the development of a grotesque cystic pseudarthrosis allowing 90 of movement together with an almost complete fibrous ankylosis of the elbow It is obvious that the pseudocyst formation was initiated by movement of the distal part of the Kuntscher nail

We have never seen anything like this before nor have we been able to trace any publication of animal experiments in which attempts have been made to transform tubular bone to cystic bone of neoplastic type

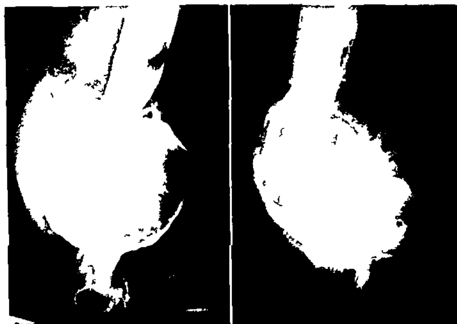


Figure 5 Same patient six months after extraction of the nail Even here there seems to be a tendency for the cyst to decrease in size

It appears that the spherical cyst will diminish after the nails have been extracted (Figure 2) According to Linneus Stenram (1965) only two cases of malignant transformation of human bone due to an implant have been published (Schinz 1952 McDougall 1956) We present these cases as examples of the tolerance of human bone to chemical and above all mechanical irritation by a foreign body

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POSSIBLE SYPHILITIC SPONDYLITIS

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Accepted 26 1 73

Among the infectious diseases affecting the spine syphilis is very rare The changes due to syphilis are gummatous spondylitis and Charcot s arthropathy

Charcot s arthropathy is a trophic complication of neurosyphilis It is usually found in the mobile part of the spine Most of these cases are symptom free Trophic destruction of the spine may lead to lesions in neural roots and/or spinal medulla

Bone syphilis is a manifestation of tertiary syphilis occurring 6-20 years after the primary infection in about 15 per cent of untreated cases (Nielsen 1950 Speed & Boyd 1936 Gjestland 1955) The superficial bones (tibia sternum and skull) are affected more often than the deep ones Of the latter gumma of the spine is so rare that only case reports have been published (Johns 1970) Distinct destruction of vertebrae is found in gummatous spondylitis The symptoms signs and x ray findings can simulate other infectious spondylites especially tuberculous spondylitis or neoplasm of the vertebral column The symptoms ensue from compression of the neural elements or destruction itself

In the following we present a case of syphilitic spondylitis

CASE REPORT

The patient a 38-year-old painter was first seen in March 1967 at the Department of Orthopaedics and Traumatology University Central Hospital Helsinki

Previously he had been in good health. The first symptoms of the present illness appeared in the spring of 1966 During heavy work he developed pain in the lumbar spine and numbness and weakness in the lower limbs

When the symptoms became worse the patient was sent to the clinic At the clinical examination the knee and ankle tendon reflexes were absent but the Lasègue sign was negative Stocking like anesthesia was found in the distal parts of the lower limbs. Bladder and bowel function was normal and the muscles intact



Figure 1 March 1967 Spondylolisthesis of 11 mm in L IV and narrowing of the intervertebral space



Figure 2 Myelography in February 1969 Spondylolisthesis in the L IV vertebra causing a total block in the subarachnoideal space

Figure 3 February 1969 Marked narrowing f the intervertebral space L IV–V and destruction of disc space and osteolytic lesions in the adjoining vert brae



Spondylolisthesis of 11 mm in LIV was seen (Figure 1) in the x ray examination and the intervertebral space L IV–V was narrowed. Myelography revealed slight narrowing of the subarachnoideal space It was considered to be due to the spondylolisthesis

In the blood tests haemoglobin was 16 4 g/100 ml the white cell count 8100/mm³ and erythrocyte sedimentation rate (ESR) 9 mm/h The routine urine tests were normal.

The patient denied that he had ever had venereal disease No signs of present or recent syphilis were found. In the serological tests for syphilis (STS) WaR and CholWaR were negative but the Kahn and VDRL (Venereal Diseases Research Laboratory) slide tests were positive The treponema pallidum immobilisation test (TPI) and fluorescent treponemal antibody te t (FTA) were positive in the serum The cerebrospinal fluid cell count was normal but liquor proteins were slightly increased (up to 2 mg/100 ml—possibl due to myelography) WaR CholWaR Kahn the VDRL slide test TI I and FTA were negative In the neurologi cal examination there were no signs compatible with neurolues The positive tests for s philis were overlooked and spondylolisthesis was considered to be the correct diagnosis Therefore the patient did not receive treatment for syphilis A back brace was made for him

In January 1969 the patient was again admitted to the hospital He had been c ntinuously dis bled for work. I ain in the lumbar area as well as numbness and tinging in the lower extremities had become v or e The clinical signs were the same as two years earlier

At x ray spondylolisthesis and the narrowing of the intervertebral pace L IV–V were more marke l than before and moreover destruction of the disc space and an



Figure 3 July 1971 Bone consolidation between vertebrae L IV and V as an end result of the inflammatory process

osteolytic lesion in the adjacent parts of the bodies were seen in the adjoining vertebra In myelography total block at the level L IV–V was found (Figure 2)

Serological and treponemal tests for syphilis in the serum and in the cerebrospinal fluid were as two years previously After consulting the venereologist at the Department of Dermatovenereology the patient received 600 000 IU of procain penicillin once a day for 15 days

Decompressing laminectomy was considered to be indicated because of progression of the neurological symptoms and the myelography finding In February 1969 laminectomy of the L IV vertebra was performed fibrocartilaginous tissue was removed from the posterior edge of the fifth vertebra and the neural elements were liberated A biopsy was taken from the spondylitic area At the histological examination this tissue was found to consist of granulomatous inflammation compatible with gummatous tissue but indistinguishable from productive tuberculosis

The post operative x ray examination disclosed a marked narrowing of the inter vertebral space L IV V and distinct spondylitic changes (Figure 3) The ESR was repeatedly under 10 mm/h and the white cell count under 10 000 mm³ In the Mantoux test 0 1 TU of PPD gave a negative result

There were no post operative complications The patient continued to use the rigid back brace He was still disabled for work as a painter or any other manual work

At the follow up examination in June 1971 the patient s subjective condition was unchanged The physical examination revealed no changes from the status in

1969 X ray examination (Figure 4) revealed bony consolidation between the fourth and fifth lumbar vertebrae as an end result of the inflammatory process

DISCUSSION

Infectious diseases of the vertebral column are still a cause of painful back The possibility must therefore constantly be borne in mind Pyogenic bacteria are as often a cause of spondylitis as Myobacterium Tuberculosis but Treponema Pallidum is a rarity (Kirkaldy Willis & Thomas 1965)

The most common syphilitic involvement of the bones is Charcot s arthropathy It is a manifestation of neurosyphilis (Drennan et al 1971) In such cases clinical signs of tabes dorsalis are to be found and the serological and treponemal tests for syphilis are constantly positive both in the serum and in the cerebrospinal fluid

Gummatous spondylitis is a manifestation of active tertiary syphilis Gumma is the syphilitic granulomatous process which destroys normal tissue i e skin and bones In tertiary syphilis the VDRL slide test is almost always positive but not the classical WaR reaction Treponemal tests (TPI and FTA) are even more sensitive and specific The VDRL test is useful as a screening test but the diagnosis of syphilis must be based on the treponemal tests In the present case WaR and CholWaR were negative but the Kahn and VDRL slide tests were positive The diagnosis was confirmed from the positive TPI and FTA

Histopathologically gumma is a necrotic homogeneous mass surrounded by mononuclear and occasionally giant cells It is sometimes difficult to differentiate from tuberculosis (Lever 1967) In our case granulomatous tissue with occasional giant cells but without necrosis or caseation was seen in the biopsy specimen one month after the antisyphilitic treatment The microscopical picture was compatible with gummatous tissue but indistinguishable from productive tuberculosis

The drug of choice in treatment of syphilis is penicillin For late syphilis 600 000 IU of procain penicillin once a day for 15 days is recommended In cases hypersensitive to penicillin 250 mg of tetracycline four times a day for four weeks is sufficient to cure the disease

The positive serological tests gradually turn to negative after the treatment more quickly the shorter the interval after infection In treated tertiary syphilis the tests will not be negative for several years if ever

Correct diagnosis and penicillin therapy are the most important

factors in the treatment of syphilitic spondylitis Antisyphilitic treatment rapidly produces ossification and bony consolidation by block vertebra Because of the rapid healing and the neoplastic nature of the lesion a fusion operation is seldom indicated (Dotter 1970 Kiraldy Willis et al 1965) Grafting is probably not necessary unless the lesion is very extensive occupying two or three vertebrae (Johns 1970) In our case decompressing laminectomy was necessary because of compression of the neural roots by pseudospondylolisthesis

It is well known that syphilitic changes may mimic many diseases Gumma of the spine can be confused with other infectious spondylites or neoplasm Although syphilitic spondylitis is a very rare disease we know that the annual number of new syphilis cases has shown a tendency to increase in recent years (Lassus 1971 Fleming & Bardenstein 1971) Therefore syphilis must be suspected in every patient with spondylitis or neoplasm of the vertebral column

SUMMARY

The syphilitic involvements of the spine are reviewed The case of a 38 year old man with gummatous spondylitis and pseudospondylolisthesis is described Progression of the neurological symptoms and grave changes seen in myelography were indications for decompression laminectomy A biopsy was taken at the operation The diagnosis of syphilis was based on the x ray findings histological evidence of granulomatous inflammation compatible with a gummatous lesion and the positive STS and TPI and FTA in the serum The patient was treated with 600 000 IU of procain penicillin daily for fifteen days Because of the neoplastic nature of the lesion a fusion operation was not performed Osseous consolidation of the affected lumbar vertebrae was seen at the follow up examination

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SOLITARY BENIGN NERVE SHEATH TUMORS AROUND THE KNEE JOINT

Report of Four Cases

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Accepted 30 i 73

Benign nerve sheath tumors of the peripheral nerves are relatively uncommon often misunderstood lesions that are seldom described in Scandinavian literature (Wadstein 1932 Pilgaard 1968) It is surprising that we have treated four cases with such tumors of the peroneal nerve around the knee joint the last year The purpose of this paper is to present these cases and to review the literature concerning benign peripheral nerve tumors especially as they occur in the lower extremity

CASE REPORTS

Case 1 was a 72 year-old driver who for one year had been conscious of a swelling in his left knee. Knocking against this swelling produced radiating pain down the leg and the great toe sometimes normal activities produced this pain for instance driving a car We found a tender round tumor situated laterally in the fossa poplitea. It measured 1 5×1 5 cm and percussion produced radiating pain as described. Neurology and EMG were normal At operation an encapsulated intraneural tumor in the common peroneal nerve was enucleated Post-operatively no complications Pathologic examination showed a typical neurilemoma.

Case 2 was a 83 year-old professor who had tightness in his right knee of six months duration and diffuse pain in his knee when he walked. He had also noticed a small tumor on the outside of his knee We found a tumor near the capitulum fibulae It measured 1×1 cm and was tender to palpation but did not give rise to radiating pain Neurology was normal At operation a multilobulated well-defined tumor was enucleated from the common peroneal nerve Postoperatively no complication Pathologic examination showed a neurilemoma (Figure 4)

Case 3 was a 43 year-old teacher who for five years had been conscious of a tender swelling in his left knee His little daughter once hit the back of his knee and he felt pain in the leg for several days Without trauma he occasionally had pain and numbness on the inside of the foot We found a very tender tumor situated laterally in the fossa poplitea It measured 2 5×3 cm and on pressure pain radiated down to the great toe. Neurology was normal. At operation a well-defined tumor

Table 1 Benign nerve sheath tumors around the knee

Case	1	2	3	4
Age (years)	72	83	43	66
Sex	male	male	male	female
Duration of symptoms	1 year	½ year	5 years	4 years
Local pain	None	Yes	Yes	None
Radiating pain	Yes	Yes	Yes	None
Tendter to palpation	Yes	Yes	Yes	Yes
Muscle weakness	None	None	None	Yes
Localisation	n peron	n. peron	n peron	n peron
Size (cm)	comm	comm	comm.	r prof
	1½×1½	1×1	2½×3	2×5
Pathology	neurinoma	neurinoma	neurinoma	neurofibroma

was enucleated from the common peroneal nerve Postoperatively no complications Pathologic examination showed a neurilemoma

Case 4 was a 66 year old farmer's wife with complaints of a swelling on the outside of her left knee and easy stumbling with her left foot for four years We found a multilobulated tumor near the capitulum fibulae It measured 5×2 cm and was somewhat tender but pressure did not produce radiating pain There was no sensory loss but decreased strength in the extensor hallucis muscle and the anterior tibialis muscle Electromyogram showed affection of the deep branch of the peroneal nerve At operation a multicystic intraneural tumor was excised from the deep branch of the peroneal nerve The tumor was not quite well defined and could not be totally removed (Figures 1 and 2) Pathologic examination showed a neurofibroma (Figure 3) Postoperatively persisting muscle weakness at six months control

DISCUSSION

There are two main forms of benign peripheral nerve tumors neurilemoma and neurifibroma (Stout 1949)

The neurilemoma is often also termed *neurinoma or Schwannoma* (Stener et al 1963) It is usually a solitary lesion but infrequently multiple lesions occur It grows slowly and is encapsulated (Harkin & Reed 1969) The tumor is mainly found in major nerves cranial and spinal nerve roots and peripheral nerves usually on the flexor aspects of the limbs especially near the wrist elbow and knee (Bick 1931 Biggart 1949 Dinaker & Balaparameswara 1971 *Rosenthal 1971*) *Neurilemoma* of the peroneal nerve near the capitulum fibulae has been reported by so many authors (Das Gupta et al 1969 Ferguson 1937 Kaplan 1968 Jenkins 1952 Cutler & Gross 1936 Wadstein 1931 and others) that it

Figure 1 Neurofibroma of the left peroneal nerve near the capitulum fibulae An intraneural multilobulated tumor

Figure 2 The same patient as in Figure 1 The neurofibroma is dissected free from the nerve The nerve fibers around the tumor are straightened



Figure 3 Neurofibroma. Connective tissue stroma irregularly arranged spindle cells and reticulin fibers Thickened arteries and cysts are not seen here in contrast to neurilemoma

has been suggested that this nerve is especially prone to develop these tumors The size of the tumor may vary the smaller ones are round and elastic but the bigger are often multilobulated with cystic degenera tions centrally The tumor usually has an eccentric position in the nerve pushing the nerve fibres to one side and is covered by a capsule Enucleation is considered to be the best treatment incision parallel with the nerve in the epineurium on the side of the tumor and blunt dissection without damage to the nerve fasciculi

Neurofibroma sometimes called plexiform benign neurilemoma may be found as solitary lesions but are more commonly known as multiple neurofibromatosis or von Recklinghausen s disease (Livingstone 1947 Biggart 1949) They occur more often on the trunk subcutaneously than on the extremities where they may involve the major nerve trunks The tumor grows without a capsule is invasive and is sometimes cystic centrally Radical excision is difficult Nerve resection and suture has been recommended if the risk of recurrence is considered to be high (Cutler & Gross 1936) If the growth of the tumor makes nerve suture impossible or if the loss of function cannot be compensated for by

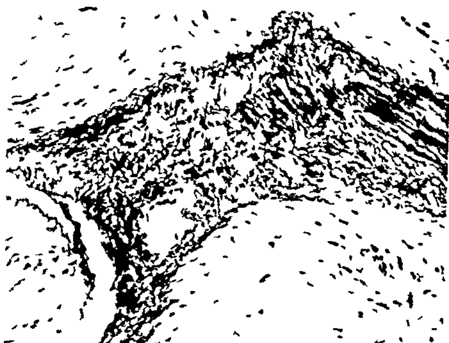


Figure 5. Neurilemoma. In the middle Antoni B tissue with cysts and irregularly arranged pleomorphic cells and fibers. In the corners Antoni A tissue: spindle cells with oval palisading nuclei.

tendon transfers, only biopsy for pathologic examination may suffice (Byrne & Cahill 1961).

On light microscopic examination of neurilemoma two types of tissue have been described: Antoni A and B tissue (Figure 5). Electron microscope reveals in the type A tissue many thin processes from the cell bodies. Under examination with light microscopy the *neurofibroma* consists of a dense connective tissue stroma (Figure 6). Examination with the electron microscope shows that the principal neurofibroma cells have dense and few cytoplasmatic processes (Fisher & Vuzevski 1968, Harkin & Reed 1969).

Malignant transformation of an encapsulated neurilemoma is denied by most authors but has been described (Carstens & Schrodt 1969, Das Gupta et al. 1969, Epstein 1971). About half of all neurogenic sarcomas arise from neurofibromas and approximately 15 per cent of neurofibromas transform into a neurogenic sarcoma (Stout 1958, Cutler & Gross 1936).

Both the neurilemoma and the neurofibroma often grow as symptomless masses that are sometimes tender and may produce pares-

thesias radiating pains and decrease of sensibility but less often weakness of the muscles The differential diagnosis preoperatively may be difficult (Buck Gramcko 1958) Ganglion was suspected in our case 1 where also the possibility of lipoma or fibroma was discussed Case 3 had been interpreted as a Baker s cyst and in case 4 the patient believed the tumor was a varicose vein This difficulty in making the right diagnosis preoperatively is well known in White s (1967) material of 45 patients only five had a correct preoperative diagnosis

During examination of patients with pain one should remember these tumors Case 1 for instance had pain in the leg that simulated a L 5 syndrome Case 4 suffered from peroneal paralysis and had electromyographic changes All the described tumors in the peroneal nerve were tender on palpation The tumor is sometimes movable from side to side but not longitudinally along the nerve trunk None of our patients had von Recklinghausen s disease

SUMMARY

Benign tumors of the peripheral nerves are considered to be rather rare During the last year we have operated upon four patients with such lesions of the peroneal nerve around the knee joint Diagnosis preoperatively was often obscure Tender masses without neurologic disturbances were most common Enucleation is recommended The literature is examined considering similarities and differences between neurilemomas and neurofibromas

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POPLITEAL CYST

A follow up study on 42 operatively treated patients

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It is generally known that popliteal cysts may develop in conjunction with both extra and intra articular diseases of the knee region Adams (1840) observed a mass in the popliteal space in patients with rheuma toid arthritis (RA) and Baker (1877) found synovial cysts in patients with knee joint disease

In an investigation on cadavers Wilson et al (1938) detected a communication between the semimembranous bursa and the normal knee joint in about 50 per cent of cases Later several authors have noted that cysts tend to be associated with other abnormalities of the knee joint (Haggart 1938 Childress 1954 1970 Burleson et al 1956) Diseases of the knee may cause popliteal cysts and vice versa gas trocnemius semimembranosus bursitis may cause intermittent effusion of the joint

Many authors have reported some cases of rupture of a popliteal cyst and formation of a dissecting giant cyst extending as far as the distal part of the calf e g Dixon & Grant 1964 Burleson et al 1956 Harvey & Corcos 1960 Tait et al 1965 Perri et al 1968)

In the present series of 42 operatively treated patients the value of extirpation of the cyst alone or extirpation in conjunction with some other procedure usually synovectomy of the knee joint was assessed

MATERIAL AND METHODS

The series comprises 42 operatively treated patients admitted for treatment to the Department of Orthopedics and Traumatology Helsinki University Central Hospital and the Kivela Hospital Helsinki from 1960 to 1971 Since 8 patients had bilateral cysts the total number of operatively treated cysts was 50 Eleven cysts extended as far as the distal part of the calf (Figure 1) Four of these patients showed acute symptoms resembling those of acute deep thrombophlebitis All patients with giant







Figure 1 a–b A giant cyst on a 0-year old rheumatoid patient. Synovectomy and extirpation of the cyst were carried out on the same occasion with a good result.

1 c A side view of another giant cyst with a remarkable narrowing of the middle part of the cyst which is lying under the tension of the popliteal fascia and the gastrocnemius muscle.

cysts were operated on within three months Two patients had bilateral giant cysts

Of the patients 25 were females and 17 males 26 cysts were in the left 24 in the right popliteal space At the time of operation the age of the patients ranged from 22 to 71 years the mean being 48 years The age of the patients with giant cysts ranged from 37 to 66 years the mean being 43 years Nearly all cysts were operatively treated within twelve months from the time of the appearance of symptoms Four patients had had almost symptomless cysts for many years Symptoms such as a sensation of fullness aching pain and limitation of motion were slight The 11 giant cysts caused more acute pain and swelling

Effusion of the knee joint was found preoperatively in 29 patients In some patients it may have been intermittent In 6 patients this symptom was less apparent and 7 patients had no effusion RA was diagnosed in 28 patients osteoarthritis of the knee joint in 3 patients osteochondritis dissecans with corpus *liberum in one patient, torn posterior part of the medial meniscus in one patient* Two patients had a history of slight trauma

Table 1 Associated diseases in 42 patients with popliteal cysts

Associated disease	No of cases	No of patients
Rheumatoid arthritis	32	28
Osteoarthritis	4	3
Osteochondritis dissecans (loose body)	1	1
Torn meniscus	1	1
Total	38	33

Table 2 Type of surgery in 50 popliteal cysts

Extirpation alone	38 (including [illegible]2 rheumatoid knee joints)
Combined with synovectomy and meniscectomy	10 (including 4 giant cysts)
Extirpation of medial meniscus	1
Extirpation of corpus liberum and shaving of cartilage	1
Total	50 cases (42 patients)

RA was diagnosed in 10 patients about one year before extirpation of the cyst whereas 18 patients had RA of long standing All giant cysts were present in RA patients. In 3 of these cases the duration of RA was under one year

In 46 cases the cyst communicated with the joint In 3 cases the communication was uncertain and in one case there was no communication. X ray changes of the

knee joint were slight In the rheumatoid cases osteoporosis and slight erosions in one half of the cases were observed Preoperative arthrography was made in half the cases and the cyst could be demonstrated in all of these.

The cyst was totally excised in all cases The communication within the joint was closed. In the patients with giant cysts the defect in the capsule was closed with fascia from the gastrocnemius semimembranosus muscles In ten patients with RA synovectomy including meniscectomy was made at the same time. In ?2 cases the cyst alone was excised Extirpation of the medial meniscus and the cyst was done in one case extirpation of the corpus liberum and shaving of osteochondritic foci of the medial femoral condyle in one case In 4 patients with giant cysts synovectomy was carried out on the same occasion In 7 cases the cyst alone was excised

The cysts were invariably situated in the typical location in the medial part of the popliteal fossa between the semimembranosus gastrocnemius muscles. Vacuum was used in the synovectomized cases and in the calf after the extirpation of giant cysts All operations of giant cysts and all synovectomies were done by the author The remaining patients were operated on by other surgeons

RESULTS

All patients were summoned to follow up examination one to ten years (average three years) after the primary operation Follow up results were obtained in 42 patients In addition to ordinary radiography arthrography was made in 15 patients Recurrence of the cyst was found in 6 patients in one bilaterally In this case osteoarthritic changes were present in both knees and reoperation was not performed In the



Figure 2 Moderate effusion and a large suprapatellar recessus of the knee joint at the follow-up despite the synovectomy and extirpation of a giant cyst Stretching of the posterior wall of the joint was demonstrated

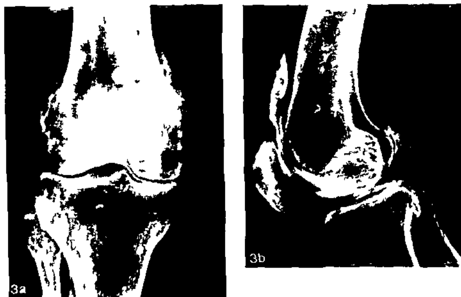


Figure 3 a–b A good result after the synovectomy and excision of a giant popliteal cyst Synovitis and the recidive formation of a cyst were not observed

remaining 5 patients a repeat operation was made Osteoarthritis was diagnosed in one patient and in one patient progressive rheumatoid inflammation of the knee joint and staphylococcus aureus infection of the wound were assumed to be the cause of recurrence of a giant cyst In this case synovectomy and re excision of the cyst performed later after healing of the infection gave a disappearance of the cyst In the remaining 3 patients there were no changes in the knee joint accounting for the recurrence which probably was bursal in origin

In this series synovectomy was done in 10 cases In 3 cases moderate effusion of the knee joint was present at follow up despite the synovectomy but there was no recurrence of the cyst Stretching and bulging of the posterior wall of the joint was demonstrated by arthrography (Figure 2) Slight or moderate rheumatoid synovitis was present in 9 of the remaining 22 rheumatoid cases in which synovectomy was not done

A giant cyst alone was removed in 7 instances Synovectomy was not done since there was only slight synovitis In 4 of these cases radiography revealed progression of rheumatoid changes and there was clinically moderate effusion synovectomy was planned As men-

tioned above the popliteal cyst recurred in one case because of infection and severe rheumatoid synovitis of the knee joint In 4 cases synovectomy was done at the same time as excision of the giant cyst and no recurrence of effusion or of the cyst was observed at follow up (Figure 3)

DISCUSSION

In 34 out of 82 operatively treated patients Burleson et al (1956) observed associated diseases mainly osteoarthritis and RA Childress (1970) recommended very careful examination of the menisci because a torn posterior horn of the medial meniscus may be the primary cause of failure of the knee and the cyst a secondary phenomenon In this series only 7 patients showed no noncomitant disease The large number of rheumatoid patients (28) is probably due to selection of the patients who are admitted to hospital This is the cause of the predominance of females Communication of the cyst with the knee joint was observed in most cases in this series

The same phenomenon has been described by other authors (Burleson et al 1956 Childress 1970) Burleson et al noticed no disposition to recurrence if the connection in the capsule was not closed but Childress preferred closure of the capsular defect in any event in elderly patients with osteoarthritis or RA In this series the capsular defect was closed with fascia from the gastrocnemius semimembranosus fascia and seemed to be justified

Perri et al (1968) reported on 6 giant synovial cysts in patients with RA According to Perri et al contrast arthrography should always be considered if a patient with RA shows calf pain and swelling In the present study arthrography was performed on all patients with giant cysts No complications occurred This investigation shows that a popliteal cyst may develop rapidly as was the case in 10 patients with RA of less than one year s duration However cysts are usually found in patients who have suffered from RA for many years

The X ray changes of the knee joint were throughout astonishingly slight in the present patients with giant cysts No severe rheumatoid destructions were seen Cyst formation seems to be related to severe or chronic soft tissue inflammation with slight changes of the cartilage and bone Jayson et al (1970) reported that with increasing volume of a simulated effusion rupture of the synovium occurred in the controls and in the early stage in rheumatoid knees not in joints showing advanced rheumatoid changes

CONCLUSIONS

Preoperative arthrography is indicated if there is any suspicion of intra articular lesions In rheumatoid patients it seems to be right to extirpate the popliteral cyst first and perform synovectomy later if necessary Patients with osteoarthritic changes of the knee show a striking tendency towards recurrence The cyst must be totally excised and closure of the capsular defect may be recommended

All patients with dissecting giant cysts had RA Extirpation of a giant cyst and synovectomy of the knee may be done in one phase but synovectomy may also be done later if this procedure proves necessary

SUMMARY

A total of 50 popliteal cysts in 42 patients were operatively treated A diagnosis of rheumatoid arthritis (RA) was made in 28 patients A dissecting popliteal giant cyst extending as far as the distal part of the calf was observed in 9 patients in 2 patients bilaterally (altogether 11 giant cysts) All these cysts were rheumatoid in origin In the majority of cases (46) the communication between the cyst and the joint was closed Preoperative X ray changes of the knee were in general slight The cyst alone was extirpated in 38 cases and in 10 cases 4 of which were giant cysts synovectomy including meniscectomy was carried out at the same time All these patients had sever rheumatoid synovitis of the knee joint Recurrence of the cyst was observed at follow up in 6 patients in one patient bilaterally In 4 cases the failure was attributed to osteoarthrotic or rheumatoid changes of the knee whereas in 3 cases no changes in the knee joint were found In a total of 12 rheumatoid cases slight progression of RA or intermittent synovitis was observed at follow up but a palpable recurrent cyst was only detected in one patient No recurrence was observed in the 10 synovectomized cases

In rheumatoid patients it seems right to extirpate the cyst first and carry out synovectomy later if necessary Other possible failures of the knee joint should be diagnosed preoperatively and treated

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FRACTURES OF TIBIAL CONDYLES

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Received 9 II 73

Despite the frequent occurrence of fractures of the tibial condyles the principles of their treatment are still debated Disagreement concerning the significance of anatomical reduction divides the surgeons into adherents of conservative therapy and advocates of surgery The purpose of the present investigation was to analyse the factors influencing the end results and assess the indications for various therapies on this basis

MATERIAL AND METHODS

During the period 1962–1967 291 patients with tibial condylar fractures were treated at the Department of Orthopaedics and Traumatology University Central Hospital Helsinki At the time of this study 33 of these patients had died and the addresses of 61 patients were unknown. The hospital records of these two groups of patients however permitted the conclusion that there was no difference between them and the remainder This report is concerned only with the remaining 197 patients 90 males and 107 females who were clinically and radiologically followed up Their mean age at the time of injury was 52 years The interval between injury and follow up ranged from 2–9 years the average being 4 5 years.

The causes of injury appear in Table 1 Traffic accidents were the cause in over half the cases The injured were pedestrians almost as often as occupants or drivers of various vehicles

The fractures were classified as suggested by Hohl & Luck (1956) (Figure 1) Fractures involving the articular surface but *lacking more than 3 mm displacement* as shown by radiography were thus termed undisplaced fractures (36 patients) The depth of the depression was measured either from the remaining intact articular surface or from a line drawn as an extension of the other tibial condyle to the point of maximum depression The displaced fractures were divided into (1) the local depression type (89 patients) with comminution of the articular surface (2) the total depression type (22 patients) with depression of the entire intact articulating surface of the condyle (3) the split type (19 patients) in which lateral displacement without depression was the presenting feature and (4) the bicondylar type

(31 patients) The lateral condyle was involved in 128 cases of monocondylar fracture the medial condyle in 38

The methods of treatment appear in Table 2

Table 1 Causes of injury in tibial condyle fractures

Causes of injury	Total
Traffic accidents	
Injuries to car occupants	22
Car injuries to pedestrians	41
Motorcycle or bicycle injuries to driver	32
Motorcycle or bicycle injuries to pedestrians	7
Fall twist or both	93
Unknown	2
Total	197

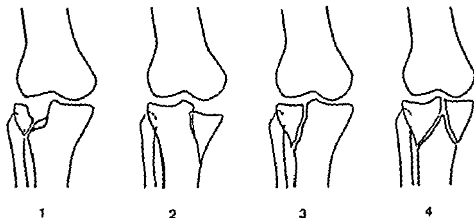


Figure 1 1 The local depression type 2 The total depression type 3 The split type 4 The bicondylar type

Conservative Treatment

Over half the patients (53 per cent) were conservatively treated Early mobilization was used in some cases but the majority were treated by immobilization in a plaster cast In some of the patients reduction of the fracture by manipulation was the first measure attempted

Operative Treatment

Most of the patients with dislocated fractures (91 or 70 per cent) were operatively treated The majority (70 patients) were operated on 1–3 days from the accident the remainder (21 patients) 4–11 days from injury The limb was exsanguinated

during operation The fracture was exposed by an incision which also permitted exploration of the joint A ruptured meniscus (44/91 patients) was excised whereas a meniscus partly torn from its marginal attachment and a meniscus that had been detached to permit better visualization of the fracture were fixed with sutures The depressed fragments of the articular surface were elevated The cavity thus created in the spongy bone was packed with heterogenous kiel bone (37 patients) or autogenous bone (18 patients) taken from the iliac crest or femoral condyle The fracture was usually (64/91 patients or 70 per cent) fixed with Ackerman s (through and through) bolt A screw was used in 8 cases and in 19 no internal fixation was done restoration of the articular surface being the only procedure carried out. In connection with operation of the fracture, torn ligaments of the knee were primarily sutured in 24 patients The medial collateral ligament was torn in 16 cases the lateral collateral ligament in 2 and the cruciate ligaments in 13 In one case early amputation was done owing to a vascular lesion The postoperative treatment consisted of active exercise in traction in 12 cases and immobilization in a plaster cast in 79/91 (90 per cent) Postoperative wound infection developed in 3 cases in one leading to osteitis which healed after trepanation performed five weeks after the primary operation Postoperative venous thrombosis developed in 5 patients in one resulting in permanent disability No postoperative deaths occurred

Table 2 Present series of 197 fractures of the tibial condyle classified by types of the fracture and method of treatment

Method of treatment	Monocondylar fractures					
	Undisplaced	Local depression	Total depression	Split	Bicondylar fractures	Total
Cast immobilization without reduction	36	26	3	3	7	75
Closed reduction followed by cast	–	9	1	4	9	23
Early mobilization without operation	–	4	1	1	1	7
Open reduction followed by cast	–	43	14	9	13	79
Open reduction followed by early mobilization in traction	–	7	2	2	1	12
Primary amputation	–	–	1	–	–	1
Total	36	89	22	19	31	197

The average duration of plaster immobilization was 9 4 weeks in both the conservatively and surgically treated cases The average time of non weight bearing was 11 7 weeks in both groups

RESULTS

The functional and anatomical end results were separately rated as acceptable or unacceptable A result was considered functionally acceptable if the patient was able to do work corresponding to his occupation or age if there was full extension of the knee with flexion of at least 90 and the knee subjectively stable and if the patient only experienced transient pain occasionally in connection with exertion A result was considered anatomically acceptable if the articular surface was dislocated by a maximum of 3 mm varus/valgus was under 10 and there was no or only minimal arthrosis The ratio of anatomically acceptable results was 123/197 (62 per cent) 77 were treated conservatively and 46 operatively The ratio of functionally acceptable results was 147/197 (75 per cent) 91 were treated conservatively and 56 operatively An extension deficiency of 5–10 remained in 21 patients (11 per cent) and 8 (4 per cent) showed an extension deficiency of at least 20 Ankylosis developed spontaneously in two knees and arthrodesis was performed on one knee A limitation of flexion by a maximum of 20 was noted in 37 patients (19 per cent) a limitation by 30–40 in 15 patients (8 per cent) and limitation by over 50 in 4 (2 per cent) Slight arthrosis was present in 39 patients (20 per cent) moderate arthrosis in 35 (18 per cent) and marked arthrosis in 28 (14 per cent) whereas no arthrosis was discovered in 95 patients (48 per cent) Among 36 patients with primarily undislocated fractures 31 showed no arthrosis 4 showed slight arthrosis and one moderate arthrosis In the 161 patients with primary dislocation the development of arthrosis was compared to the results attained by reduction (see below) Good reduction was associated with minimal late arthrosis in 28 cases with moderate arthrosis in 17 and with marked arthrosis in 15 No arthrosis developed in 55 of the satisfactorily reduced cases When the result of reduction was poor (widening or depression of the articular surface by at least 5 mm and/or valgus/varus over 10) no arthrosis resulted in 8 cases moderate arthrosis in 17 and marked arthrosis in 13 Residual valgus was observed in 41 knees (20 per cent) residual varus in 7 (3 5 per cent) No varus deformity was over 10 The valgus deformities were a maximum of 10 in 34 cases and 20–30 in 7

The treatment of the menisci in connection with operation seemed to have no effect on the end results

When the cancellous bone defect was filled with a bone graft the kind of graft had no effect on the overall results However when the

primary defect was large (10 mm at least) the Kiel bone seemed to be less resistant to compression than autogenous bone (Wilppula & Bakalim 1972 a)

Forty patients showed insufficiency of the ligaments of the knee at follow up The insufficiency was mostly slight but in 9 cases it was considered to be the main cause of a functionally unacceptable result (Wilppula & Bakalim 1972 b)

The position of the fracture was impaired during the observation time in 27 patients *In this group the average duration of non weight* bearing was 11 5 weeks The treatment was operative in 23 cases conservative in 4

There was no correlation between the functional end results and the age of the patients or the duration of immobilization although healing was more rapid in those patients who were mobilized early

The relationship between the end results and the different types of fracture and the different methods of treatment appears in Tables 3–10

Table 3 Results in undisplaced fractures

Method of treatment	Anatomical results acceptable	Functional results acceptable	Total
Cast immobilization	36	35	36

Undisplaced Fractures (Table 3)

All of the 36 patients with undisplaced fractures were conservatively treated by cast immobilization The anatomical result was acceptable in all cases and the functional result was unacceptable in only one

Local Depression Fractures (Table 4)

In 50 surgically treated patients the depth of the primary depression averaged 8 5 mm In 39 conservatively treated cases the primary depression was an average of 5 mm The original position of the fracture or the position attained by reduction deteriorated in 17 cases Of these patients 3 had been conservatively treated 14 operatively

The relationship between the results of reduction and the functional end results is shown in Table 5 *When the depth of the depression* was under 5 mm after reduction or attempted reduction a significantly (X = 5 4) better result was obtained than in those cases where reduction had been less successful The tendency was the same in the con

servatively and operatively treated groups The data for the two groups are pooled in the table

Table 4 Results in local depression fractures treated by various methods

Method of treatment	Anatomical results acceptable	Functional results acceptable	Total
Conservative treatment			
Cast immobilization	18	27	35
Early mobilization	3	3	4
Operative treatment			
Cast immobilization	22	24	43
Early mobilization in traction	5	5	7
Total	48	59	89

Table 5 Functional results compared to accuracy of reduction in local depression fractures

Depression after reduction	Functional results		Total
	Acceptable	Unacceptable	
0–4 mm	47	15	62
5 mm	13	14	27
Total	60	29	89

Table 6 Results in total depression fractures treated by various methods

Method of treatment	Anatomical results acceptable	Functional results acceptable	Total
Conservative treatment			
Cast immobilization	4	4	4
Early mobilization	1	1	1
Operative treatment			
Cast immobilization	6	7	14
Early mobilization in traction		1	2
Primary amputation	–		1
Total	11	13	22

Table 7 Functional results compared to accuracy of reduction in total depression fractures

Depression after reduction	Functional results		Total
	Acceptable	Unacceptable	
0–4 mm	12	6	18
5 mm	1	2	3
Total	13	8	21

Table 8 Results in split fractures treated by various methods

Method of treatment	Anatomical results acceptable	Functional results acceptable	Total
Conservative treatment			
Cast immobilization	6	7	7
Early mobilization	1	1	1
Operative treatment			
Cast immobilization	7	9	9
Early mobilization in traction	2	2	2
Total	16	19	19

Total Depression Fractures (Table 6)

In this group 16/22 patients were surgically treated The depth of the depression averaged 9 7 mm A vascular lesion necessitated early amputation in one case Among the 5 conservatively treated patients 4 had a primary depression of 3 5 mm and one had a deeper depression The position of the fracture deteriorated during the observation time in 5 patients 4 of whom had been operatively treated one conservatively

The relationship between the results of reduction and the functional end results appears in Table 7 A good result of reduction (depression under 5 mm) correlated with an acceptable end result

Split Fractures (Table 8)

Of 19 patients 11 were operatively treated The functional end result was acceptable in all The 8 conservatively treated patients also had acceptable functional results in spite of residual widening of the fracture line by 3–7 mm in 5 cases

Bicondylar Fractures (Table 9)

The apparently better results of conservative treatment of this type of fracture may be due to the relatively greater frequency of slight primary dislocation (depression or widening under 5 mm) in the conservatively treated patients (12/17) compared to the surgically treated patients (2/14).

The result of reduction was considered to be good if the depression or widening was under 5 mm and valgus/varus angulation under 10°. As may be seen in Table 10, the correlation was striking between a good result of reduction and an acceptable functional end result.

The alignment was impaired during the time of observation in 5 operatively treated patients.

Table 9. Results in bicondylar y and t fractures treated by various methods

Method of treatment	Anatomical results acceptable	Functional results acceptable	Total
Conservative treatment			
Cast immobilization	8	12	16
Early mobilization	–	1	1
Operative treatment			
Cast immobilization	4	8	13
Early mobilization in traction	–	–	1
Total	12	21	31

Table 10. Functional results compared to accuracy of reduction in bicondylar y and t fractures

Result of reduction	Functional results: Acceptable	Functional results: Unacceptable	Total
Good	15	2	17
Poor	6	8	14
Total	21	10	31

DISCUSSION

The significance of anatomical restoration of the articular surface is still a matter of debate. Hohl & Luck (1956) showed experimentally

that the area of the defect in the tibial articular surface was gradually replaced with cartilaginous tissue. Similar observations have been made in human beings in connection with arthrography (Dovey & Heerfordt 1970) and with arthrotomy (Maisel & Cornell 1948, Reibel & Wade 1962). The above mentioned authors emphasized the favourable effect of mobilization of the joint. Early activation also prevented the formation of intra-articular adhesions (Hohl & Luck 1956). These observations speak in favour of Apley's (1956) argument for recommending conservative treatment: "moulding movement is the best way to achieve the greatest congruity of the joint surfaces". Conservative treatment in which early mobilization of the knee is a leading principle has many adherents (e.g. De Morgues & Chaix 1964, Barrington & Dewar 1965, Poulsen & Tophøj 1969).

Not all investigators, however, rely on the healing forces of nature alone but think that in any event the worst deformities of the joint surface ought to be repaired. Operative reduction has thus been considered indicated if condylar depression or widening of the fracture line exceeds ¼ inch (Gylling & Lindholm 1953, Wolf & White 1963), if the depth of the depression is over 10 mm (Hohl & Luck 1956, Porter 1970, Lucht & Pilgaard 1971) or a minimum of 5 mm (Palmer 1951, Hohl 1967), or if the depression is 3–4 mm (Perey 1952). Other authors have emphasized the importance of exact reduction in general (Jakobsen 1953, Solonen 1963, Fryjordet 1967).

As regards the clinical material of the present retrospective study, the tendency seems to have been to treat the worst fractures surgically and less badly dislocated cases conservatively. Hence the number of comparable cases was not large enough to permit evaluation of the relative merits of the different methods of treatment. But we assessed the effect of the alignment achieved by reduction or attempted on the end results. The best functional results were attained in undislocated and split type fractures lacking a depression. Moreover, a significant correlation was observed between a good result of reduction and a good functional end result in fractures of the local and total depression types as well as in bicondylar fractures. A similar correlation was discovered between the results of reduction and the development of late arthrosis. On the basis of these observations we recommend anatomical restoration of the articular surface whenever possible. As a rule this is not feasible without operation. However, if the original depression of the joint surface is slight (under 5 mm), the position of the fracture may often be accepted and the patient may be conservatively treated. The

operation as such did not seem to have any detrimental effects and a further advantage of surgery is the possibility of simultaneously repairing soft tissue injuries Ligamentous insufficiency was the main cause of an unacceptable result in 4 5 per cent of cases in the present series and we consider primary repair of totally ruptured ligaments to be desirable in connection with the treatment of tibial condylar fractures (Wilppula & Bakalim 1972 b) However it is useless to suggest any fixed rules as to the kind of dislocation requiring operative treatment since the individual needs of the patient and his possibilities of receiving efficient after treatment must be taken into account (Hohl 1967)

The trend in the treatment of tibial condylar fractures is clearly in favour of early mobilization (e g Charnley 1967 Reibel & Wade 1962 Solonen 1963 De Morgues & Chaix 1964 Barrington & Dewar 1965 Fryjordet 1967 Porter 1970 Rasmussen 1971 Lucht & Pilgaard 1971) although the meaning of this phrase as used by different authors varies from mobilization started after a few days to after several months A relatively long period of immobilization 2 months has also been recommended (Chinnard 1964) Although our clinic has also gone in for a reduction of the period of immobilization the average duration was still relatively long (9 4 weeks) in the present series Despite this the end results were very good and no significant effect of the duration of immobilization on the results could be demonstrated As a general impression it may however be stated that early mobilization seemed to accelerate the restoration of a normal range of movement of the knee (Solonen 1963) A relatively long period of immobilization seems to be compensated by efficient controlled after treatment Manipulation under anaesthesia has proved useful in cases where the return of full mobility of the knee came to a standstill (Chinnard 1964)

As regards the duration of non weight bearing in tibial condylar fractures there is a high degree of consensus in the literature Most authors have recommended 10 12 weeks non weight bearing (e g Palmer 1939 Jakobsen 1953 Jensenius Jensen & Nielsen 1961 Reibel & Wade 1962 Solonen 1963 Jonasch 1965 Fryjordet 1967 Rasmussen 1971) The average duration of non weight bearing in the present series 11 7 weeks is in agreement with this general trend Hohl (1967) suggested non weight bearing for as much as 6 months In the present series redepression occurred in 27 cases This seems to suggest that a prolonged period of non weight bearing may be indicated in some cases

SUMMARY

A series of 197 patients with tibial condylar fractures was retrospectively studied The treatment was conservative in 53 per cent Of the dislocated fractures 79 per cent were operatively treated There was a strong correlation between a good result of reduction and a good functional end result Operative reduction is recommended Ligamentous tears often occur in conjunction with tibial condylar fractures and it is suggested that these lesions be primarily treated by surgery A relatively long period of immobilization does not necessarily exclude a good end result provided that mobilizing after treatment is controlled

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INTRAMEDULLARY NAILING OF TIBIAL SHAFT FRACTURES

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Accepted 6 ii 73

For a long time intramedullary nailing has been used in the treatment of shaft fractures In 1950 Kuntscher (1962) introduced reaming of the medullary cavity prior to insertion of the nail – one of the greatest advantages in modern operative fracture treatment Furthermore the use of the TV image intensifier has made nailing easier and safer and considerably improved closed nailing

For tibial shaft fractures closed nailing has great advantage because accurate reduction is possible without exposing the fracture thus avoiding compromising further the soft tissues which may already have been severely damaged at the accident Rigid fixation is usually achieved giving the best conditions both for healing of the fracture and the soft tissues

In our general surgical department intramedullary nailing has been used to an increasing extent especially after 1967 when we started using the AO instrumentarium We have reviewed the case histories and x rays of the patients treated with intramedullary nailing for tibial shaft fractures in the period 1952–71 and performed a clinical and roentgenological follow up

MATERIAL AND METHODS

In all 81 patients (61 males and 20 females) had intramedullary nailing for 85 tibial shaft fractures 4 patients had bilateral fractures. Younger males predominated but nailing was also performed in older patients (Figure 1) Traffic accidents accounted for about 85 per cent (Table 1) consequently associated injuries were common ([illegible]3 per cent) (Table 2)

The *fracture types* are summarized in Table 3 The fracture was located in the middle third of the shaft in 65 cases The majority were comminuted (Figures 2–5) and/or open but a distinction has to be made between a small puncture wound caused by dislocated fragments penetrating from inside and the larger soft tissues

Table 1 Circumstances of injury

	No
Road traffic accidents	69
Accidents at work	4
Sport injuries	4
Others	4
Total	81

Table 2 91 associated injuries in 60 patients

Type		No
Head		40
Thoracic injury		3
Pelvic fracture		5
Fracture of upper limb		8
Fracture of ipsilateral femur		15
Fracture of contralateral lower limb		20
femur	8	
tibia	12	
Total		91

Table 3 Fracture type

Type		No
Comminuted		35
Segmental	4	
Transverse	16	
Transverse		28
Oblique		9
Segmental		7
Other		6
Total		85

injury commonly produced by direct trauma. Of the 35 open fractures, 18 were open through puncture wounds and 17 had larger wounds.

The *treatment* is summarized in Table 4. As a routine, the patients are operated upon under general or epidural anaesthesia, preferably on a traction table with the

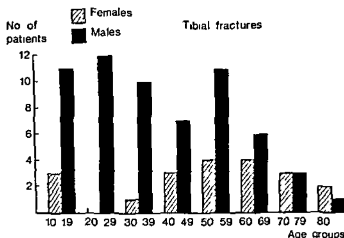


Figure 1 Distribution by age and sex

knee flexed to 90 or more A small skin incision is made slightly proximal to the tibial tuberosity With an awl a hole is made in the cortex and the first part of the canal is made. Thereupon the guide wire is introduced under visual control by the TV image intensifier Most fractures are easily reduced by traction and manipulation Reaming is thought essential When the nail has been driven home traction is released and a few heavy but considerate blows will impact the fragments Vacuum drainage is sometimes used The leg is elevated on a frame for 2–3 days After this time the patient may start active exercises and is up and around on crutches in 4–5 days In stable transverse fractures weight bearing is allowed after 2 weeks

The treatment of choice is primary nailing e.g within 8 hours This was performed in 22 patients 6 of whom had open fractures In patients with multiple injuries the tibial fracture was deemed of secondary priority and skeletal traction or plaster applied The same applies to most of the open fractures Among the patients primarily treated by traction many were nailed within one week of the accident and all within 4 weeks In patients primarily treated with plaster nailing was postponed for peri ds varying from 2 weeks to 5 months In 8 patients other types of osteosynthesis (e g plates Parham s band, etc) had primarily been performed up to 2 years previously

Open nailing was performed in 25 cases and in 6 of these supplementary cerclage was found necessary because of butterfly fragments In later years closed nailing has been preferred Reaming was done in 71 fractures but was not performed in some cases from the e rlier part of the period, n r was this always done in segmental fractures In 23 patients a post-operative plaster was applied either because the osteosynthesis was not deemed exercise stal le r the patient deemed non cooperative (chronic alcoholics etc) In about 10 per cent of the cases the osteosynthesis was deemed rigid enough to allow primary weight bearing (e g. transverse fractures after 2 weeks) Among the other patients full weight bearing was allowed within a mean of 4 months after the operation



Figure 2 Male aged 26 years run over by his own car (a) Typical comminuted fracture with butterfly fragment caused by direct trauma (b) Six weeks after nailing

Complications are listed in Table 5 There were 3 deaths 2 from head injury and one from pulmonary embolism Among *operative* complications comminution predominated either during the reaming or the hammering of the nail In no case was the healing of the fracture impaired We included smaller fragmentation and only one case of larger fragmentation was encountered Penetration of the guide wire and locking of the same was uncommon and had no harmful effect All these complications are avoided by adhering to a strict technique and by using adequate instrumentarium

Postoperative complications were similar to those that may occur after any operative procedure and were not particular numerous No case of deep infection was encountered

Re operation was found necessary in 9 patients (Table 6) mostly in the earlier part of the period Re nailing was the usual procedure in most cases because too thin a nail had primarily been inserted In some of these patients reaming had not



Figure 3 Male aged 20 years injured in a car accident (a) Typical transverse fracture with small butterfly fragment caused by direct trauma (b) Eight months after nailing

been performed as mentioned above (in the first part of the period in some segmental fractures etc) Two cases of non union occurred (1) A comminuted open severely displaced fracture had been nailed with a V formed nail without reaming The fixation was supplemented by 2 Parham s bands and a plaster re nailed with re ming 9 months later (2) A severely comminuted segmental fracture was nailed and 2 wires and plaster also u ed [illegible]0 months later re operation with a sliding graft without removal of the nail Both fractures healed One patient was re nailed because of a refracture after premature removal of the primary nail

Follow-up

Of the 48 patients 2 could not be traced The remaining 46 patients were followed up clinically and roentgenologically with a mean observation period of 2½ years

Table 4 Primary treatment

Primary treatment	No
Skeletal traction	46
Intramedullary nailing	22
Plaster	9
Other osteosyntheses	8
Total	85

Table 5 Complications

Complication		No
Operative		10
Comminution	8	
Penetration of guide wire	1	
Locking of guide wire	1	
Postoperative		12
Local		
Wound infection	3	
Wound hematoma	2	
Leg thrombosis	2	
General		
Serum hepatitis	1	
Bronchopneumonia	1	
Pulmonary embolism	3	
Total		22

Table 6 Re operations

Type		No
Re nailing		8
Nail too thin	5	
Non union	1	
Varus malunion	1	
Re fracture (original nail removed too early)	1	
Sliding graft operation		1
Total		9

Table 7 Follow-up results

Evaluation	No of patients
Good (healing in normal alignment no symptoms or signs)	67
Fair (slight symptoms or signs, not incapacitated for work or everyday life	6
Poor (non union marked deformity incapacitated for work or everyday life	3
Total	76

Although admirable results may be achieved with intramedullary nailing of tibial shaft fractures without reaming (Zucman & Maurer 1970) and with supplementary plaster immobilization we prefer nailing after reaming in accordance with the present day technique elaborated by Kuntscher (1962) In most cases this will secure an absolute rigid immobilization of the fracture thus making plaster superfluous The patient then gains the enormous advantage of being able to exercise his muscles and joints while the fracture heals Furthermore reaming will markedly diminish or even abolish the risk of comminution of the bone when the nail is hammered home and also eliminates the complication of jamming the nail In addition a most important point is that the reaming will make it possible to use a *thick* nail which will prevent bending and thereby counteract malunion This was stressed by Kuntscher (1962) and again by Bottger et al (1970)

Reaming may not always be advisable in segmental fractures as it may result in rotation or twisting of intermediate fragments thus depriving them of their blood supply These fractures are also difficult to treat with closed methods and even operative procedures are liable to a high frequency of complications i e when using plates screws wires and Parham s bands In such cases a thin intramedullary nail may be used in some cases supplemented by plaster (Figure 6) Zucman & Maurer (1969) claim good results with this method Re nailing with reaming after 6–8 weeks may be considered

The discussion whether to perform the osteosynthesis primarily or secondarily i e after healing of the skin wound has not yet been settled Many authors now strongly recommend primary nailing of open fractures and claim excellent results (Staudacher 1962 Tscherne et al 1967 Decoulx et al 1969 Schcuba 1969 Arzinger & Riedeberger

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Sliding graft operation		1
Total		9

organisms found in open infected fractures are hospital bacteria which invade the wound from ambulance personnel nurses doctors and *not* organisms found primarily in the contaminated wound (Arzinger & Riedeberger 1969) This fact underlines the necessity of treating open fractures according to the strictest aseptic rules i e the wound should be covered with a sterile dressing at the scene of the accident and not removed until the patient is in the operating theatre

SUMMARY

The good results of intramedullary nailing of tibial shaft fractures are illustrated in a series of 81 patients who were either primarily or secondarily nailed Reaming was performed in most cases A rigid fixation was secured in most patients

At the follow up of 76 patients the results were good or fair in 96 per cent In addition 2 patients had a good result after re nailing only one patient had a poor functional end result

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TARSOMETATARSAL FRACTURE-DISLOCATION

Late results in 26 patients

EERO WILIPULA

Accepted 12 i 73

The anatomy and mechanism of fracture dislocation of Lisfranc s joint or the tarso metatarsal articular complex have been extensively described in the literature (Quenu & Kuss 1909 Holstein & Joldersma 1950 Jeffreys 1963 Aitken & Poulson 1963) The treatment was previously conservative (Quenu & Kuss 1909 Grunert 1910 Weber 1933) but more recently open reduction has been advocated (Geckeler 1949 Del Sel 1955 Granberry & Lipscomb 1962 Cassebaum 1964 English 1964) Comprehensive analyses of late results are not available however owing to the small number of cases in most reports For this reason the present study was undertaken

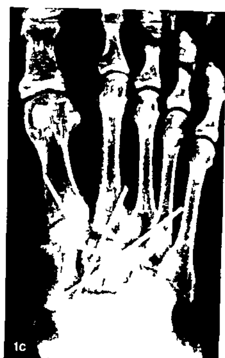
MATERIALS AND METHODS

The series consist of 26 patients with fracture dislocation of Lisfranc s joint treated at the Department of Orthopaedics and Traumatology during the period 1955–1967 Of these patients 21 were male and 5 female The age range was from 14–60 years average 32 years The follow up time was 2–10 years average 5 years

The cause of injury was twisting of the foot in slipping or falling in 11 cases a crush injury in 8 cases and a traffic accident in 7 cases

The cases were classified according to which metatarsal bones (= M) the dislocated segment of the foot comprised (Table 1) The first metatarsal was dislocated in either the medial or (dorso) lateral direction the other metatarsal bones invariably in the dorsolateral direction The second to fifth metatarsals remained fixed to each other and were dislocated as one block The first metatarsal either remained in place or was dislocated together with the remainder or moved in the opposite direction (diverging dislocation) Often a wide diastasis occurred at the base between the first and the second metatarsals but distally the bones always remained fixed so that no spreading of the forefoot resulted In addition the tarsal bones most usually the cuneiforms often showed fractures and dislocations which have not been separately considered in the classification Concomitant fractures of the metatarsal bones were present in 18/26 patients Chip fractures in the area of


1a


1c


1b


1d
1e

Lisfranc s joint which are often not definitely diagnosed until operation have not been considered in the table A compound injury was involved in 6 cases

Table 1 Different types of dislocation of Lisfranc s joint and concomitant fractures of the foot (M = metatarsal bone)

Dislocated segment	Total	Other fractures					
		Digitus	Metatarsal	Cuneiform	Cuboideus	Calcaneus	Malleolus
M 1	1	1	1	–	–	–	–
M 2–3	1	–	1	–	1	1	–
M 3–5	1	–	–	–	1	–	–
M 2–5	12	1	7	3	–	–	–
M 1–5	9	–	5	4	3	–	1
M 1 & M 2–5 (divergent)	2	–	2	–	–	–	–
	26	2	16	7	5	1	1

METHOD OF TREATMENT

Open reduction and internal fixation were carried out in 8 patients Seven were operated on within 24 hours from the accident while in one case open reduction was carried out on the ninth day from injury A longitudinal incision between the first and the second metatarsals was carried to the dorsum of the foot These bones are in a key position in reduction When they were accurately aligned the remainder easily fell in place In correspondence with the segmental dislocation pattern described above Reduction was difficult in two cases owing to interposition of the tendon of the tibialis anterior in the first cuneometatarsal joint and in another two cases owing to severe comminution of the cuneiform bones (Figures 1 and 2) In two patients a second longitudinal incision was made more laterally For fixation Kirschner wires were inserted through the proximal portion of the metatarsal bones transarticularly to the tarsal bones The first cuneo metatarsal joint was fixed by one wire The segment formed by the other metatarsal bones was fixed with one to three wires In one case the first and the second cuneiforms were in addition fixed by a staple The Kirschner wires were cut subcutaneously In one patient the base of the second metatarsal was fixed to the first cuneiform with chromic catgut inserted through a drill hole in the bone Postoperatively the foot was always placed in a plaster boot

Figure 1 (A–B) Dorsolateral dislocation of all metatarsals Interposition of the tendon of tibialis anterior in the first cuneometatarsal joint Dorsal artery of the foot ruptured and the posterior tibial artery in spasm which was relieved by reduction (C) After internal fixation with Kirschner wires (D–E) After 4 ½ years Patient satisfied


2a


2b


2c


2d

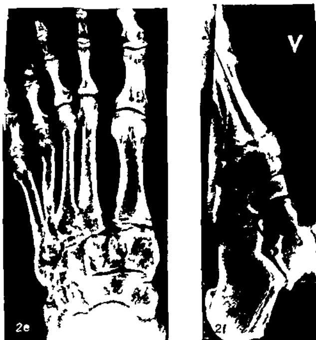


Figure 2 (A–B) Compound dorsolateral dislocation of all metatarsals Distal articular surface of the first cuneiform included in the loose fragment (C–D) After reduction and internal fixation with Kirschner wires Necrosis of wound margins developed which later required skin grafting (E–F) After three years Patient is satisfied Slight limitation of twist movement of the tars metatarsal joints

The treatment was conservative in 18 cases Closed reduction and immobilization in plaster were used in 14 cases In one of these skin traction was transiently applied. Four patients were treated by skeletal traction in conjunction with immobilization in plaster

All procedures were carried out under general or spinal anesthesia. The operations were performed with the help of a tourniquet. The length of immobilization in plaster was 4–14 weeks, average 8 weeks Skeletal traction was used for 3–7 weeks average 4 weeks The duration of non weight bearing was 1–12 weeks average 6 weeks The Kirschner wires were removed under local anaesthesia after an average of 12 weeks the range being from 8–25 The patients were unable to work for 2–15 months average 6 months. Skin necrosis requiring skin grafting, developed in three cases of compound injury including one that was internally fixed In one compound case the fifth metatarsal bone had to be amputated owing to osteitis

Circulatory disturbances In one patient showing dislocation of all metatarsal bones and compound fracture of the medial malleolus the foot was cold pale and pulseless before operation The dorsal artery of the foot was ruptured and the posterior tibial artery was in spasm After reduction the circulation started again and no sequalae occurred.

LATE RESULTS

The results were classified as follows

Functional results

Good only slight subjective complaints not influencing the ability to work not more than slight limitation of movements no local tenderness or painful movements in the foot standing on the toes not difficult *Fair* moderate pain on exertion considerable discomfort under particularly stressing conditions moderate limitation of movements in the foot definite pain on palpation or movement standing on the toes difficult *Poor* marked continuous pain affecting the ability to work pain invariably in walking considerable limitation of movements in the foot definite local tenderness or painful movements standing on the toes difficult

Table 2 Late results in Lisfranc's fracture dislocations

Dislocated segment and treatment	Total number of cases	Functional result			Anatomical result		
		Good	Fair	Poor	Good	Fair	Poor
Operative treatment							
M 2–5	2	–	1	1	1	–	1
M 1–5	6	4	1	1	4	1	1
Conservative treatment							
M 1	1	1	–	–	1	–	–
M 2–3	1	–	1	–	1		–
M 3–5	1	1	–	–	1	–	–
M 2–5	10	3	4	3	3	2	5
M 1–5	3	–	2	1	1	–	2
M 1 & M 2–5	2	–	–	2	–		2
	26	9	9	8	12	3	11

Anatomical results (based on clinical and radiological examinations)

Good good total shape of the foot diastasis at the base between the first and the second metatarsals not more than 5 mm perhaps slight arthrosis *Fair* like the foregoing except that separation between the first and the second metatarsals was 6–9 mm possibly slight or moderate arthrosis *Poor* marked deformity (cavus abduction or adduction shortening first metatarsal dislocated) diastasis between the

first and the second metatarsals 10 mm or more perhaps moderate or severe arthrosis

The distribution of the results according to the type of injury involved is shown in Table 2 The results were better when only one to three metatarsals were dislocated than in the cases involving injury to four or five of these bones In the former case good results were attained by conservative treatment In the case of more extensive dislocation *the results of open reduction were better* The subjective state sometimes continued to improve for four or five years In many cases an arch support was prescribed after removal of the plaster boot At follow up five patients stated that they still needed an arch support All of these had functionally poor results

The results of reduction were separately evaluated *Open reduction* resulted in a permanently good shape of the foot in 5/8 patients In two cases poor alignment and poor anatomical result were attributed to technical failures in the operation In one patient in whom chromic catgut was used for fixation an initially good result ended in being classified as fair *Closed reduction* resulted in a permanently good shape of the foot in 4/18 patients In 2/18 a fair result was obtained In 3 the alignment could be classified as primarily good In 7/18 patients in whom closed reduction was attempted the shape of the foot remained poor This group includes the cases treated by skeletal traction In two patients good alignment was attained by closed reduction but later the result deteriorated into poor

Table 3 Anatomical and functional end results in tarsometatarsal fracture dislocations

		Functional results			Total
		Good	Fair	Poor	
Anatomical results	Good	9	3	–	12
	Fair	–	3	–	3
	Poor	–	3	8	11
Total		9	9	8	26

Table 3 shows the distribution of the patients according to the anatomical and the functional end results The conclusion is drawn that the two are correlated Fractures of the foot concomitant with the injury to Lisfranc s joint did not seem to influence the end results

Limitation of motion in the foot and toes was noted in both opera

tively and conservatively treated patients (in a total of 12/26) though in more marked form in the latter Hallux rigidus (dorsal flexion less than half of the normal) was observed in 6 patients Two of these were treated by open reduction Passive twisting of the tarsometatarsal joint was limited in 8 patients including one treated by open reduction Motion of the subtalo midtarsal joints was limited in 8 patients including 3 operatively treated cases The lesser toes showed limitation of motion in 4 conservatively treated patients Limitation of motion was observed in 9/18 of the conservatively treated and 3/8 of the operatively treated cases Considerable limitation of motion was observed in 5/11 patients with anatomically poor results Slight limitation of motion was noted in 1/12 patients with anatomically good results

Considerable deformity (anatomically poor result) was noticed in 11 patients Seven of these showed malposition of cavus type and one showed abduction deformity of the forefoot Separation of the first and second metatarsal bones by 10 mm or more was present in 5 cases Three patients showed marked hammer toes Pes planus did not occur

Arthrosis of the tarso metatarsal and the tarsal joints was observed in 15/26 patients The most severe changes were noticed in patients with marked deformities Slight arthrosis occurred irrespective of a good shape of the foot

DISCUSSION

When the metatarsal bones are dislocated at the tarso metatarsal joints the first metatarsal is separated from the remainder, which often dislocate as one block Moreover there may be concomitant fractures of the cuneiform bones (Quenu & Kuss 1909 Collet et al 1958) The deep transverse ligament keeps the distal ends of the metatarsal bones together despite their separation at the base and fracturing of the diaphyses This segmental dislocation pattern must be kept in mind in the choice of technique for reduction

Gissane (1951) emphasized the risk of gangrene if reduction is delayed Before reduction one patient in the present series showed grave circulatory disturbance in the foot The relief of vascular spasm requires prompt reduction

Patients able to use their feet despite persistent dislocation have been described (Cotton 1924 Aitken & Poulsen 1963) Of the present patients even those who had markedly deformed feet (Figure 3) were able to work although not in heavy occupations On the other hand a good anatomical result was no guarantee for a symptom free foot In



Figure 3 Unreduced diverging dis[illegible] Considerable pain in daily activities but [illegible] arch supp[illegible]

general however a good anatomical [illegible] tional result We therefore agree w[illegible] emphasized the importance of good [illegible] berry & Lipscomb 1962 Cassebaum [illegible] (about 5 mm) at the base between the bones may be accepted if the shape [illegible] some cases good alignment is certai[illegible] and immobilization in plaster (Morr[illegible] Joldersma 1950) However the prese[illegible] inadequacy of conservative treatment failure or only transiently successful conservative treatment were best m[illegible] or a maximum of three metatarsal b[illegible] location was so slight that the alignm[illegible] as good In severe cases a plaster boot bones in alignment and if the foot [illegible]

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hazard The present results support the view that open reduction and internal fixation are more reliable (Allan 1947 Del Sel 1955 Granberry & Lipscomb 1962) and that reduction may be hindered by small fragments detached from the metatarsal and tarsal bones (Allan 1947 Collet et al 1958 Cassebaum 1964) by dislocation of the cuneiform bones (Holstein & Joldersma 1950) or by interposition of the tendon of tibialis anterior (Holstein & Joldersma 1950 Jeffreys 1963) For internal fixation Kirschner wires proved useful which is in agreement with previous recommendations (Geckeler 1949 Holstein & Joldersma 1950 Del Sel 1955 Collet et al 1958 Lange 1967)

In the case of traumatic arthrosis of the tarso metatarsal joints arthrodesis has been recommended (Compere et al 1963) Primary arthrodesis has also been suggested in the treatment of dislocation injuries on the ground that this procedure is often nevertheless indicated later (Granberry & Lipscomb 1962) Niederecker (1956) recommended primary arthrodesis in dislocation fractures of the first cuneo metatarsal joint in particular Arthrodesis was not performed in any of the present patients The symptoms tended to subside gradually during a period of several years In some instances it is possible that arthrodesis would have accelerated the recovery and in the presence of protracted disabling symptoms it seems wise to consider cuneo metatarsal arthrodesis

The average duration of immobilization in plaster was 8 weeks and the average duration of non weight bearing was 6 weeks This corresponds to the recommendations of previous authors (Morrison 1937 Allan 1947, Aitken & Poulson 1963 Cassebaum 1964) Limitation of motion in the foot and toes was present in 12/26 patients It seems likely that persistent limitation of motion could be reduced by cutting down the duration of immobilization and by intensifying the mobilizing exercises during after treatment The postoperative prevention of oedema is certainly important from the outset when either the feet or the hands are involved

SUMMARY

The late results in 26 fracture dislocations of Lisfranc s joint are presented The average follow up time was 5 years In the majority of cases (23/26) four or five metatarsal bones were dislocated Eight patients were treated by open reduction and internal fixation with Kirschner wires and 18 patients were conservatively treated Good

alignment is worth striving for and operative treatment gave good results The usefulness of postoperative mobilization is emphasized

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KNUD JANSEN

September 22nd, 1913

This volume of Acta Orthopaedica Scandinavica is dedicated to Knud Jansen on his 60th birthday as a tribute to his outstanding contributions as editor, head of department, president, and organizer and in recognition of the inspiration he has been to fellow workers in all fields of orthopaedic surgery

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THE UPPER EXTREMITY

THE LOWER EXTREMITY

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Nuffield Orthopaedic Centre Oxford England

A NEW PROJECTIONAL LOOK AT ARTICULATED SCOLIOTIC SPINES

GRAHAM DEANE & ROBERT B DUTHIE

Accepted 9 iii 73

Anatomical analyses of scoliotic spines present considerable difficulties and the voluminous literature only indicates the complexity of the subject rather than its solution Clinical research based upon standard radiography has helped in understanding aetiology and epidemiology classification and differentiation of the types as well as the various patterns of deterioration However the actual structural deformity and its mechanism of development still remains obscure The source of such information is to be found in articulated macerated specimens of complete but scoliotic spines Obviously one is only studying the deformity of bones and their articulations without the all important supporting structures of muscles ligaments and in some cases the thoracic cage and pelvis Even so this type of material which is very rare because of the loss during the War of Schmorl s collection in Dresden and the Hunterian collection at the Royal College of Surgeons of England has been discovered in the museum of the Royal College of Surgeons Edinburgh Single specimens have been submitted to mensuration dissection and usual radiography by Roaf (1971) who described how the structural rotation was associated with increase in the length of the anterior vertebrae with an excessive growth of the articular processes and laminae Langenskiold (1971) has also observed the abnormal growth of the posterior elements in experimental scoliosis of the rabbit The biomechanical stabilizing effect upon axial rotation of the posterior element e g facet joints laminae and ligaments has been described by White & Hirsch (1971) from their experiments in cadaveric thoracic spines

Results from studies of five articulated scoliotic spines by a new projectional method for rotation for linear relationship of the vertebral bodies to their posterior elements and for changes in the compensatory curves will now be presented

means of this serial linear tomography. *All radiographs were taken with the speci*mens both marked and unmarked. In the marked series lead "strips" were attached to the vertebral bodies anteriorly and lead "diamonds" attached to the tips of the spinous processes. A flexible rod was introduced along the spinal canal in two spines without damaging the specimens, but in two this was not possible and in the fifth a rod was already in place.

RESULTS

Linear surface measurements

The individual anterior vertebral body lengths for the normal and scoliotic spines have been made non dimensional for comparison and are represented in the following graphs.

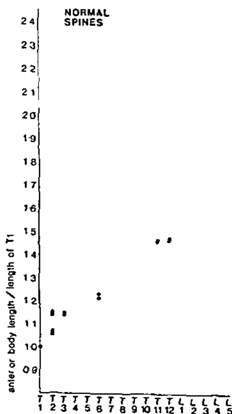
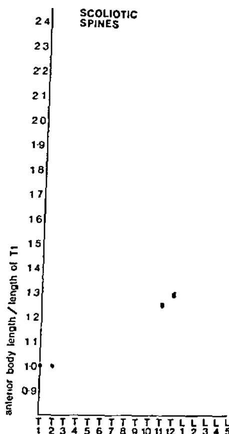


Figure 1 Normal spines
Individual anterior vertebral body lengths expressed as a ratio of the length of T1

Figure 2 Scoliotic spines Individual anterior vertebral body lengths expressed as a ratio of the length of T1



This showed that the length of the vertebral bodies as expected became longer as one progressed down the vertebral column from upper thoracic to lower lumbar The slope of the graphs showed that this occurred at an equal rate both in the normal and scoliotic spines

The total linear measurements of both the normal and scoliotic spines are shown in Table 2 It was found that the length of the normal anterior vertebral bodies i e 450 mm on average was almost the same as the length of the scoliotic vertebral bodies i e 447 mm on average (Table 2) However the posterior length in the normal spines was on average 446 mm i e similar to the anterior lengths but in the scoliotic spine there was significant reduction in length to 397 mm on average The lengths of the individual primary and compensatory curves in the scoliotic specimens are presented in Tables 3 and 4 Measurement of the primary curves demonstrated a kyphosis in four specimens and a lordosis in one (Table 3) The compensatory curves were measured

Table 2 Total length of thoraco lumbar spine (mm) measured along veterbral bodies (anterior) and spinous processes (posterior)

		Anterior (mm)		Posterior (mm)	
Normal	1	440		450	
	2	415		420	
	3	495		470	
		Average length	450 mm	Average length	446 mm
Scoliotic	1	445		330	
	2	435		405	
	3	470		430	
	4	440		425	
	5	390		320	
		Average length	447 mm	Average length	397 mm

This specimen was from a child and therefore not included in the averages of the adult spines

Table 3 Anterior and posterior lengths of primary curves

	Extent of curve	Anterior (mm)	Posterior (mm)
1	T6–L1	110	77
2	T7–L1	195	205
3	T4–T12	220	230
4	T3–T9	150	185
5	T4–T12	190	195

Table 4 Added anterior and posterior lengths of compensatory curves (above & below)

	Anterior (mm)	Posterior (mm)
1	235	253
2	240	200
3	250	200
4	290	240
5	200	125



Figure 3 a Standard antero posterior radiograph of specimen 1 – b Standard lateral radiograph of specimen 1

(Table 4) and showed that where there was a kyphosis i e specimens 2 3 4 and 5 there was a compensatory lordosis On the contrary where there was a lordosis in specimen 1—the compensatory curves were kyphotic

Radiographic analysis

The results for specimen 1 are fully illustrated (Figures 3 9) and are a typical example

The results of the radiographic measurements in all the specimens are given in Table 5 with additional notes on other findings The finding common to all specimens was the relatively small deviation from the midline of the spinous processes (Figures 5 and 6) and the



Figure 4 Oblique radiograph of specimen 1 showing that positioning of the spine relative to x ray projection concealed the true severity of the curve measured in the standard way

greatest rotatory distortion was seen in the vertebral body The relationship of the spinal canal to the spinous processes was less abnormal (Figures 5 and 6) The rotational deformity extended beyond the limits of the primary scoliotic curvature in most specimens

The degree of rotation was always maximum at the apex of the primary curve It did not bear a proportional relationship to the measurement of lateral deviation by Cobb s method (Table 5)

DISCUSSION

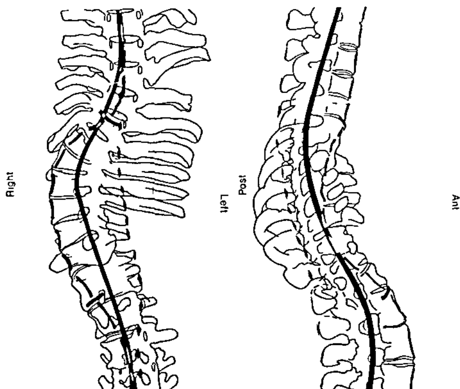
The results of measurement showed that the anterior vertebral body lengths when measured individually and as total lengths were almost normal in scoliosis However the posterior lengths were found to be considerably less than their corresponding anterior lengths in all of the scoliotic specimens Further these posterior lengths were signifi



Figure 5 Standard antero posterior (a) and lateral (b) radiographs of specimen 1 with lead markers and flexible rod in situ. Note the comparatively normal alignment of the spinous processes (diamonds) The relationship of the spinal canal to the posterior elements was distorted minimally The maximum distortion was in the anterior vertebral surfaces (vertical lead strips)

Table 5 Measurement from standard radiographs and tomographs

Specimen	Standard measurement of curve	Max measured rotation at apex of primary curve
1	72	[illegible]3
2	36	63
3	32	19
4	71	[illegible]3
5	118	[illegible]9



Figures 6 a & b Diagrams to illustrate Figure 5

cantly reduced from those of the normal spines This observation was found in all specimens whether the primary curve was kyphotic or lordotic. It appeared therefore that the compensatory curves in the kyphotic type may not be only compensatory but may in addition have some primary growth disturbance leading to a shorter total posterior length In the normal spines as expected the normal thoracic kyphosis was balanced by the lumbar lordosis with all linear measurements being equal Therefore longitudinal vertebral body growth would seem to be normal in scoliosis although the posterior elements of the established curve appeared to have become shorter than normal regardless of the type of curve that had developed

From the radiographs it is obvious that the standard scoliosis views do not give a full or accurate interpretation of the complex three dimensional curvature that characterises the deformity The standard measurement of curvature by Cobb s method for the quantitative as



Figure 7 a. Transverse axial radiograph through the total length of marked specimen 1 showing the complexity of the curve and again the minimal distortion away from the mid line of the spinous processes (above centre)

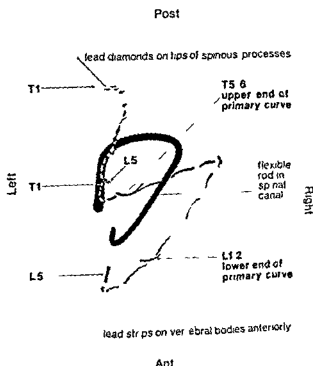


Figure 7 b Diagram to illustrate the above

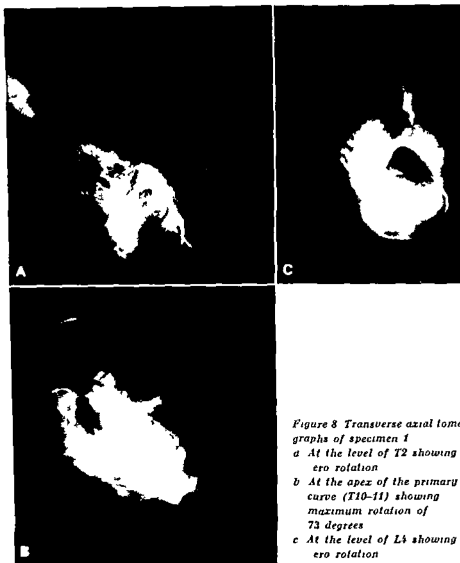


Figure 8 Transverse axial tomographs of specimen 1
a At the level of T2 showing ero rotation
b At the apex of the primary curve (T10–11) showing maximum rotation of 73 degrees
c At the level of L4 showing ero rotation

sessment of the progress of the deformity and the result of treatment is liable to error by small alterations in the positioning of the patient Cobb s method can only measure the lateral deviation of the spine and any assessment of rotation is only an approximation From this study it is clear that the new transverse axial tomography demonstrated the degree of vertebral rotation present in the curve and this was measur

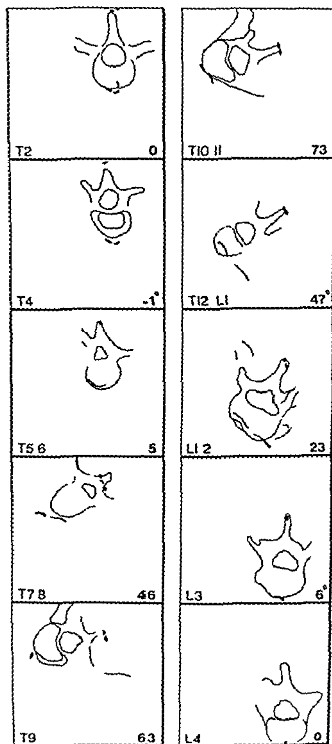


Figure 9 Diagrams traced from the transverse axial tomographs of specimen 1 at 3 cm intervals demonstrating the degree of axial rotation through the specimen

able Because this deformity is always present in structural scoliosis and is the most difficult to correct it is of clinical importance to attempt this type of study in patients Single transverse axial tomography has been described by Takahashi (1969) for outlining cavity pathology in patients but not as yet for spinal curvatures

It has also been observed from this study that the axis around which this rotational deformity occurred was just anterior to the tip of the spinous processes These latter structures were in the established curve least distorted from their original position confirming Langenskiold s (1972) observations However the axis around which rotation occurs in the thoracic column of normal spines is said to be near the front of the vertebral body (Davis 1959) Thus the rotational deformity of scoliosis is not an exaggeration of the rotation which is possible in a normal spine It is suggested that there is some strong inhibiting force to growth posteriorly in the spine and when combined with normal growth anteriorly the development of scoliosis with rotation and lateral deviation can occur This force may be regarded as a single longitudinal one acting upon a prismatic column similar to that which D Arcy Thompson (1942) observed from anthropological studies of animal horn spirals This he pointed out as behaving quite differently from that of a cylindrical column in that it underwent a torque movement with deformation of its components (Duthie 1971) The spinal column in the erect human can be regarded as an asymmetrical or prismatic column subjected to the constant longitudinal force of gravity Therefore should any abnormal factor of localised growth inhibition or muscle imbalance arise then the longitudinal force of gravity will act away from the mid line and produce a rotation and lateral bending and thereby continue to increase this deformity Only if mid line balance is again achieved will this force cease to increase the deformity

In conclusion it is suggested that some inhibition in growth of the posterior elements of the spine may be a sufficient assymetric stimulus to allow the longitudinal force of gravity to produce the characteristic scoliotic curvature in spite of normal linear growth of the vertebral bodies anteriorly

SUMMARY

Five articulated scoliotic spines have been studied by serial transverse axial tomography for rotation and for linear relationships of the vertebral bodies to their posterior elements It was found that

1 The normal progression of increase in anterior vertebral body length down the spine has also been found in the scoliotic spine

2 The anterior body lengths either singly, or as total length were almost normal in the scolioses but the posterior lengths were considerably reduced, whether the primary curve was kyphotic or lordotic In the normal spines the linear measurements showed that the thoracic kyphosis was balanced by the lumbar lordosis

3 Standard scoliosis views by radiography do not give an accurate interpretation of the complex three dimensional curvature of scoliosis and measurement of such radiographs is very liable to error by small alterations in positioning of the spine

4 The new transverse axial tomographs demonstrated well the vertebral rotation and this was measurable Possible clinical use of this method was discussed

5 The axis of rotation occurred near the tips of the spinous processes in scoliotic spines but in the normal thoracic spine it is said to be near the front of the vertebral body Therefore the rotational deformity of scoliosis is not an exaggeration of the rotation found in normal spines

6 It was suggested that scoliosis results from some strong inhibitory force to growth of the posterior vertebral structures with normal anterior linear growth

In the presence of local growth inhibition or muscle imbalance the constant longitudinal force of gravity acting on the prism the vertebral column can satisfactorily explain the progression of the typical scoliotic deformity

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INDIVIDUAL MOLDED SEAT SHELLS FOR SEVERELY HANDICAPPED PERSONS

G G KUHN

Accepted 2 x 73

The physically handicapped person spending the greater part of the day in a chair is dependent even more than a healthy person on a well fitting seating possibility Often it is not possible for him to shift his weight to distribute pressure and increase blood circulation



Figure 1 Working chair with individual molded seat shell

Figure 2 The patient is prepared for casting The correction is obtained by pneumatic pads and extension



For these reasons it is essential that the severely handicapped person be supplied with a seat which conforms with his anatomical require ments It cannot be obtained in the available mass produced wheel chairs and their accessories We therefore decided to develop a pos sibility to build individually molded seat shells

First a chair was constructed adjustable in all parts and planes in which the patient is seated (Figure 1) The chair is then adjusted to obtain the most favorable position and correction Plaster of Paris strips are placed on the seat and back after the patient has been removed and he is then replaced in the former position (Figure 2) In this way the mold is taken After the plaster has set the patient is again removed and the mold can be reinforced

The cast which at this point can already be called a molded seat shell is installed on a base plate which can be adjusted electrically in all planes With the aid of this it is possible for the patient himself as well as for the orthotist to obtain the optimal alignment of the

Figure 3 Patient on the powered alignment unit

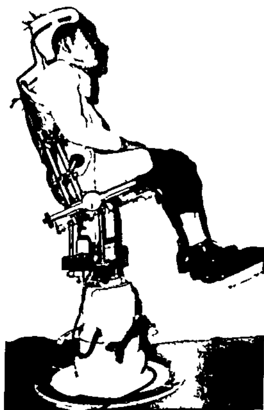


Figure 4 Lamination of the shell



Figure 5 Functional arm support on elastic rubber joint



shell (Figure 3) In this position the shell is transferred into the patient s wheelchair after which he tests it for a certain amount of time

During the trial the patient is dressed as lightly as possible to give him a better feeling of pressure areas When the patient and the orthotist are satisfied that no more adjustments are necessary and everything is as comfortable as possible a positive mold is taken of the shell It is enlarged on both sides by about 1 cm to allow for clothes If indicated Plastazote is placed on the seat and the mold will then be laminated with polyester resin as usual (Figure 4)

The brims of the shell can be finished after the resin has set and the shell is ready to be placed into the wheelchair

In all cases the shell is mounted on a base plate so that it can also be placed on an ordinary chair or into a car for example It also enables us to place the patient in a resting position if indicated

Arm and footrests are fastened directly onto the laminated shell to



Figure 6 Patient (with scoliosis) in his individual molded seat shell on the wheelchair

avoid disagreement of angle when the inclination of the shell is changed Both foot and armrests are fitted exactly to the patient s requirements (Figure 5) Other aids such as seat belts or head rests can be added if necessary

Individual molded seat shells have been fitted in our clinic for the following disabilities tetraplegia progressive muscle dystrophy neural muscle atrophy meningocele osteogenesis imperfecta primary chronic rheumatism arthrogryposis multiplex and scoliosis of different geneses and varying degrees (Figure 6)

Seat shells which are individually molded based on our method have become a valuable orthopedic aid They are often indicated have been tested extensively and are now used with a large degree of reliability by the disabled

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	Total	Tumour	Tub	Osteo
1 vertebra	35	23	5	7
2 "	93	17	34	42
3–4 "	16	7	8	1
5 or more	6	3	3	–
	150	50	50	50

The radiological findings tabulated according to the ABC of reading spinal X rays were

	Total	Tumour	Tub	Osteo
Axis – change of	90	21	35	34
Bulging of paraspinal soft tissue shadows	83	23	31	29
Corpus				
height reduction	96	30	38	28
margin erosion	140	46	47	47
structural changes	125	50	43	2[illegible]
Disc reduction	136	40	48	48
Pedicle involvement	50	31	8	11

Any deviation from the usual is recorded here as change of axis Bulging of the paraspinal soft tissue shadows includes slight and unilateral bulging which was seen

	Total	Tumour	Tub	Osteo
Unilateral or definitely asymmetrical bilateral	53	15	22	16
Bilateral symmetrical	30	8	9	13
	83	23	31	29

Disc reduction can include the total disc or part of it Structural changes in the vertebral arch can be seen in antero-posterior as well as lateral views and are often easier to discover in the antero-posterior ones

The number of patients where all the mentioned X ray findings were present compared to those with the same findings except pedicle involvement were

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TUMOUR, TUBERCULOSIS AND OSTEOMYELITIS OF THE SPINE

Differential Diagnostic Aspects

BERNHARD PALS

Accepted 23 I.73

It is well known that the differential diagnosis between tumour tuberculosis and unspecific osteomyelitis of the spine may be difficult as the symptoms and signs are very much alike This has been discussed by so many authors that there is no point in trying to give a complete list of the literature From this hospital Nissen Lie (1941) and Afvik (1951) have already discussed the problem

As the possibilities to treat these diseases improve the desirability to establish a correct diagnosis increases To get an impression of the differential diagnostic values of different clinical laboratory and radiological findings the author has reviewed records and X rays of 150 patients with spinal disease viz 50 with tumour 50 with tuberculosis and 50 with unspecific osteomyelitis

MATERIAL AND METHODS

43 of the patients with tumour had their diagnosis verified by histological examination following a biopsy of the tumour or following an autopsy and in 4 cases by histological examination of a primary tumour or metastases to lymph nodes. Patients with probable hemangioma of the spine are excluded as the diagnosis was made radiologically only and not verified by histology The types of tumours were

Cancer metastases in	23 cases
Malignant mesenchymal tumour	8
Myelomatosis	4
Plasmocytoma	4
Reticulosarcoma	3
Ewings sarcoma	2
Lymphogranulomatosis	2
Histiocytosis (eosinophilic granuloma)	1
Melanoma	1
Chondroma	1
Aneurysmal bone cyst	1
	50

The patients are reviewed as one single entity as they are too few in each category to be evaluated in different groups according to type of tumour.

Included among the tuberculous patients are only those where the diagnosis was verified by the demonstration of TB in pus or granulation tissue and/or by histological examination. Patients with palpable abscess or draining sinus are excluded as these patients do not represent the diagnostic problem under discussion.

In the group of osteomyelitis are included 29 patients where the microorganism was demonstrated (Staph. aureus in 28 of these cases) and 6 where histology was compatible with unspecific osteomyelitis. In the remaining 16 cases the diagnosis was made ex juvantibus and later good health. Six of these last cases had in addition elevated ASTA.

RESULTS

Sex and age distribution in the three groups were

	Total	Tumour	Tub	Osteo
Males	87	31	24	32
Females	63	19	26	18
	150	50	50	50
0–14 years	14	4	1	9
15–29	10	3	3	4
30–44 "	35	12	18	5
45–59	53	17	16	20
60 or more	38	14	12	12
	150	50	50	50

History and Clinical Findings

The duration of the present history before the patient consulted a doctor cannot be estimated from the records but the duration before admission to hospital was

	Total	Tumour	Tub	Osteo
Less than 3 months	51	7	5	39
3– 6	29	16	6	7
6–12	38	17	18	3
More than 12	32	10	21	1
	150	50	50	50

Acute onset of symptoms was reported in 38 patients with osteomyelitis and in only a few patients in the other two groups. Usually the first symptom was back pain, but in 22 cases the initial symptom was fever followed by chills and temperatures of 39–40° C. All of these last patients had osteomyelitis.

Back pain, stiffness of the back, pain with toe-heel fall, as well as tenderness were usual complaints in all three groups, but were not always present. Fever before or at admission was found in

Total	Tumour	Tub	Osteo
43	8	13	22

Previous tuberculosis or tuberculosis in other organs at the same time as the spinal disease under discussion was found

Total	Tumour	Tub	Osteo
42	13	24	5

Paraplegia occurred within 3 months of the first symptoms of the spinal disease, or later

	Total	Tumour	Tub	Osteo.
Within 3 months	5	4	–	1
Later	15	8	7	
	20	12	7	1

Laboratory Findings

Hemoglobin per cent	Total	Tumour	Tub	Osteo
90 or more	77	24	35	18
80–89	43	10	12	21
70–79	23	11	3	9
Less than 70	6	4	–	2
Not registered	1	1	–	–
	150	50	50	50
ESR in mm/hour				
1–10	10	5	5	–
11–19	18	7	10	1
20–49	51	16	29	6
50–69	23	11	3	9
70–99	23	9	3	11
100 or more	25	2	–	23
	150	50	50	50
Tuberculin reaction positive	125	40	50	35
Pos in age 0–14 years	8	2	1	5

Phosphatase examination was done in proportionately too few patients to be reported

Radiological Findings

Two lesions were found in 6 patients with tumour and 2 with osteomyelitis but only the one which dominated clinically and radiologically is tabulated below

The regions of spine involved were

	Total	Tumour	Tub	Osteo
Cervical spine	2	2	–	–
Thoracic "	84	27	26	31
Lumbar	64	21	24	19
	150	50	50	50

The dorsolumbar junction is here regarded as the thoracic region

The number of vertebrae involved were

	Total	Tumour	Tub	Osteo
1 vertebra	35	23	5	7
2 "	93	17	34	42
3–4	16	7	8	1
5 or more	6	3	3	–
	150	50	50	50

The radiological findings tabulated according to the ABC of reading spinal X rays were

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	83	23	31	29

Disc reduction can include the total disc or part of it Structural changes in the vertebral arch can be seen in antero posterior as well as lateral views and are often easier to discover in the antero-posterior ones

The number of patients where all the mentioned X ray findings were present compared to those with the same findings except pedicle involvement were

	Total	Tumour	Tub	Osteo
All findings present	14	3	6	5
All findings except pedicle involvement	24	1	21	2

Special Examinations

Aspiration of bulging paravertebral soft tissue shadows was often done but not always e g not in cases which were judged to be overwhelmingly probably tuberculous and radical operation was planned

Needle aspiration of the vertebrae was done in only a few cases Open surgical biopsy of the diseased vertebrae was performed in 91 patients

DISCUSSION

Only those symptoms and signs will be discussed which may be or have been reported to be of differential diagnostic value

Age between 0–14 years means some probability of osteomyelitis in this study 9 of 14 patients and very little probability of tuberculosis This demonstrates how bone and joint tuberculosis is no longer a disease of childhood in Norway Patients 60 years old or more were equally distributed in all three diagnostic groups

History of shorter duration than three months before admission to hospital indicates osteomyelitis This is just another way of saying that the symptoms from osteomyelitis are pronounced and develop rapidly (Nissen Lie 1941 Alvik 1951 Mach 1968) A history of more than 12 months suggests tuberculosis

Acute onset of symptoms indicates osteomyelitis and especially if it takes the form of fever with chills and temperatures of 39–40 C

The reviewed records do not tell whether it is typical for tumour that the back pain does not reduce following immobilisation (Bette 1955 Taubert 1958 Mach 1968 Brocher 1970)

Previous tuberculosis or tuberculosis in other places at the same time must not exclude from the mind the possibility of tumour or osteomyelitis In this study two of the tumour patients had a metastasis located to previously verified tuberculous vertebrae three had bacillary lung tuberculosis and one had bacteriologically verified hip tuberculosis at the same time as their spinal tumour

Paraplegia is said to indicate tumour and particularly if it is early (Bette 1955) This study supports the assertion to a slight degree only Paraplegia seems seldom to be due to osteomyelitis

Hemoglobin per cent below 80 strongly contradicts a diagnosis of tuberculosis

ESR 1–10 mm/hour can be seen in patients with tumour and tuberculosis but not osteomyelitis where it is seldom seen below *50 mm* According to Brocher (1970) one third of patients with tuberculosis of the spine never have elevated ESR The six patients in this study with spinal tuberculosis and ESR of more than 50 mm had the following complications lung tuberculosis and empyema pleuritis Addison s disease kidney tuberculosis paraplegia pyuria of unknown character In another group of 100 patients with tuberculosis of the *spine* the *author* found that 19 out of 20 patients with ESR 50 mm or more all had complications in the form of tuberculosis of other organs paraplegia or open sinus (Paus 1964) It seems justified to assert that ESR 50 mm or more contradicts the diagnosis of tuberculosis of the spine if there is no complication or other concomitant disease

ESR *100 mm* or more in uncomplicated cases practically proves the diagnosis of osteomyelitis

Positive tuberculin reaction was found in all the tuberculous patients in this study but can be negative (Paus 1964) The sole differential diagnostic indication the test can give is perhaps that negative reaction in age group 0–14 years excludes tuberculosis or makes it highly *improbable* Positive reaction even in this age group was seen in all groups

Schinz (1966) found that osteomyelitis most often affects the lumbar region This was not the case in this study

Schmorl & Junghans (1968) maintain that in case of metastatic tumour there are usually multiple lesions This was not the case in this study It should be regarded as accidental circumstance that none of the tuberculous patients in this study had more than one lesion

One single vertebra involved indicates a likelihood of tumour while involvement of two vertebrae indicates tuberculosis or osteomyelitis If three or more vertebrae are involved the diagnosis osteomyelitis is unlikely to be correct as earlier described (Nissen Lie 1941 Murray & Jacobson 1971)

Bulging of paraspinal soft tissue shadow unilateral or bilateral was evenly distributed in all three groups which was also Mach s (1968) observation whereas Bette (1955) Taubert (1958) and Brocher (1970)

assert that lacking or unilateral bulging indicate tumour Murray & Jacobson (1971) found the bulging larger in cases of tuberculosis than tumour and osteomyelitis As the bulging can be seen without representing an abscess the commonly used expression abscess shadow should be banned as a misnomer

Structural changes in the vertebral body indicate tumour or tuberculosis in this study as also reported by Bette (1955)

It is usually stated that the intervertebral disc retains its height in cases of tumour contrary to infectious cases (Bette 1955 Taubert 1958 Edeiken & Hodes 1967 Kohler 1967 Murray & Jacobson 1971) This study *does not support* this view as 40 out of 50 patients with tumour had reduced disc height But if the disc has retained its height *this* is an indication for tumour as was found in this study in 10 out of 14 patients Mach (1968) also regards this as almost a differential diagnostic proof

Pedicle involvement seems to represent a probability of tumour as also described by Mach (1968) and Brocher (1970) This study neither *supports the assertion that osteomyelitis affects the arch more often* than tuberculosis (Brocher 1968 Schmorl & Junghans 1968) nor the assertion that arches are more usually affected than vertebral body in osteomyelitis (Schinz 1966)

All the mentioned X ray findings could be found at the same time in all three groups but seldom However if all X ray findings were present except pedicle involvement this seemed to indicate tuberculosis The *only patient with tumour with such findings had myeloma This* confirms Brocher s (1970) assertion that myeloma has no predilection for the arch in contrast to other tumours

It continues to be impossible to establish a firm diagnosis clinically It is mandatory to get a specimen for histological and bacteriological examination This is also the only way to find out the type of tumour or bacteria and its sensitivity to chemotherapy If there is bulging soft tissue shadows an aspiration can be tried If not *only open operation* or needle aspiration biopsy remain

Operation with biopsy is recommended by Johnson et al (1953) Nagel (1965) Mach (1968) and Brocher (1970) Lichtenstein (1965) will resort to needle biopsy only if biopsy at surgery for some reason cannot be performed In contrast Coley (1960) advocates aspiration biopsy and Ottolenghi (1969) has developed the needle aspiration technique so he can use it in all regions of the spine and with *convincing* results

The risk is minimal by both methods In favour of the open method it can be said that in cases of tuberculosis the surgical treatment can be done at the same time as the biopsy Also in cases of osteomyelitis it may be of therapeutic value to open In favour of aspiration biopsy it can be said that the procedure is smaller and the patient is spared the postoperative unpleasantness which is admittedly present even if it is usually not serious

Scintimetry with ^{85}Sr (Fellander & Lindberg 1966 Fassbender et al 1969 Defiore et al 1970) reportedly give a possibility for early diagnosis of tumour tuberculosis and osteomyelitis of the spine as well as information as to the extent of the lesion But it does not give the differential diagnosis let alone the type of tumour or bacteria and its sensitivity to chemotherapy

CONCLUSIONS

The differential diagnosis between tumour tuberculosis and osteomyelitis of the spine is often difficult to establish on the basis of clinical laboratory and radiological findings alone None are pathognomonic for one or the other disease and none are always present

Tumour is somewhat probable if only one single vertebra is involved and if the X rays demonstrate the disc height retained or the pedicle involved

Tuberculosis is probable if the history exceeds twelve months and is strongly indicated if all the above mentioned X ray findings except pedicle involvement are present An age of 0–14 years contraindicates tuberculosis particularly if the tuberculin test is negative as do hemaglobin per cent below 80 and ESR 50 mm or more in uncomplicated cases

Osteomyelitis is practically certain if the onset is acute and particularly with chills and temperature of 39–40 C and if ESR is 100 mm or more It is probable if the history is shorter than three months and if the patient is 0–14 years old Contraindicating osteomyelitis are paraplegia ESR below 50 mm and if X rays show three or more vertebrae involved

To establish a definite diagnosis and also to find out which type of tumour or bacteria is present and its sensitivity to chemotherapy operation with exposure of the lesion is recommended possibly needle aspiration biopsy

SUMMARY

Records and X-rays of 50 patients with tumour, 50 with tuberculosis and 50 with unspecific osteomyelitis of the spine have been reviewed. The clinical, laboratory and radiological findings are evaluated with regard to their differential diagnostic value.

Some few may practically prove a diagnosis while others, at the most, justify a suspicion or a probability. No finding was found pathognomic or required.

To establish a firm diagnosis as well as to make out which type of tumour or bacteria is present and its sensitivity to chemotherapy, operation and open biopsy of the spinal lesion are recommended.

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TREATMENT OF PARALYSIS OF THE TRAPEZIUS MUSCLE BY THE EDEN LANGE OPERATION

A Langenskiöld & S Ryöppy

Accepted 9 iv 73

Injury to the accessory nerve formerly relatively common as the result of a stab injury or as a complication of operative procedures for tuberculosis of the lymphatic glands is now seen more seldom and usually as a closed injury caused for instance by traffic accidents It is followed by a paralysis of the trapezius and the sternocleidomastoideus muscles

The upper portion of the trapezius muscle elevates the scapula the lower portion draws it downwards One of the functions of all the three portions is to draw the scapula towards the midline The upper and lower trapezius together with the levator scapulae the rhomboids and the serratus anterior muscles control the rotatory movement of the scapula without which the abduction of the arm is limited to 80 (Benninghoff 1949 Dewar & Harris 1950) As a result of the paralysis of the trapezius muscle a drop shoulder with rotation of the angle of the scapula towards the midline and restricted abduction of the arm is caused The muscular imbalance results in anterior and rotatory displacement of the scapula The shoulder drop often causes traction on the brachial plexus with paraesthesia and radiating pain in the upper extremity The overstrain of the remaining muscles may result in pain These symptoms often indicate an operative correction of the condition

The fixation of the scapula by fascial slings to the spinous processes has been used by some authors (Szubinski 1920 Henry 1927 Dickson 1937) Because of the complicated function of the trapezius these procedures could not give very satisfying results Therefore myoplastic operations have been strived for (Dewar & Harris 1950)

Because only very few reports on the results of the myoplastic operations have been published in the literature we feel it justified to

present the follow up results in three patients treated by an operation originally designed by Eden (1924) and later developed by Lange (1951, 1959).

OPERATIVE METHOD

The technique described in detail by Lange (1951, 1959) was used with only slight modifications. A slightly curved incision extending from the dorsal aspect of the acromion to the medial inferior border of the scapula was used. The levator scapulae muscle was detached from the scapula with a piece of bone prepared free by blunt dissection in the proximal direction and fixed with some sutures of unresorbable material to the lateral part of the scapula close to the acromioclavicular joint. The scapula was held in an elevated and adducted position during the fixation. The infraspinatus muscle was detached subperiosteally from the scapula. The rhomboids were detached with a piece of bone from the medial margin of the scapula and drawn laterally, holding the scapula in an adducted position, and fixed with moderate tension to the bone by sutures of unresorbable material through bore holes in the scapula. The infraspinatus muscle was sutured again on the rhomboids. The arm was immobilised in a thoracobrachial plaster cast for four weeks, after which active exercises were begun.

RESULTS

The subjective result in all three cases was good. All patients experienced increased stability of the shoulder, marked diminution or total disappearance of the pain in the shoulder, relief of paraesthesia and improved abduction of the arm. The drop shoulder position was corrected totally in all cases. The rotatory malposition of the scapula was markedly improved or totally corrected. The rotatory movement of the scapula was not fully corrected and this caused slight difficulty and residual pain. All three patients were able to do their previous work after the operation.

CASE REPORTS

Case 1. A. K., housewife, 38 years of age at operation, had been in a train accident in 1944, thirteen years before the admission. She had received a closed injury to the right shoulder region with paralysis of the trapezius muscle as the result. The situation became worse with time, making housework more and more difficult because of pain in the shoulder and paraesthesia in the upper extremity. At ad-





Figure 1 Case 1 The paralysis of the right trapezius resulted in a shoulder drop and rotatory malposition of the scapula. The state before (A) and one year after operative correction by the technique of Eden and Lange (B)

mission she had a typical drop shoulder (Figure 1 A) with forward dislocation and rotation of the scapula The active abduction of the arm was 40 When the scapula was passively fixed in normal position the active abduction of the arm was normal *Operation* on 13 April *1957* After the operation (Figure 1 B) the position of the scapula in the resting state was normal and the active abduction of the arm was full with slight difficulty between 70 and 100 of abduction The pain had disappeared and the patient was able to do all her daily housework The situation was unchanged during the follow up time of fifteen years

Case 2 F K aged 44 years at operation a male sales agent In a car accident he had received a rupture of the acromioclavicular joint a fracture of the scapula at the base of the acromion a cerebral contusion and fractures of several ribs with haemothorax In the carotid angiography an avascular area in the parietal region and a little intracerebral haematoma were seen Unconsciousness of several days cleared up gradually and the patient was back to work four weeks later At the follow up examination the patient complained of difficulties in his work arising from poor memory and slowness of thinking as well as pain and weakness of the shoulder The latter was thought to be caused by the untreated acromioclavicular injury until a typical shoulder drop (Figure 2 A) with weakness of the trapezius was diagnosed. The active abduction of the arm was hampered but the range of movement was normal In the electromyography the upper portion of the trapezius showed diminution of the motor units and polyfacicity of the individual motor potentials *Operation* on 8 March *1971* The patient assumed his previous work three months after the operation The configuration of the shoulders at rest was almost symmetrical (Figure 2 B) The elevation power of the shoulder had clearly

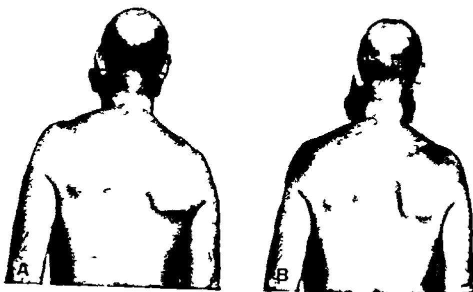


Figure 2 Case 2 Partial paralysis of the right trape ius Before (A) and after (B) operative correction

increased and the active abduction of the arm was free. The result was subjectively good. There was slight pain in the acromioclavicular region in lifting of moderately heavy objects and some sensation of weakness The residual symptoms were interpreted mainly as the result of the subluxation of the acromioclavicular joint. During the time of follow up of two years the situation has been unchanged

Case 3 A.J., aged 39 years at the second operation a female assistant in a secretarial office. The patient fell while skiing at the age of nine (in 1941) and a stick penetrated her neck from the supraclavicular region to the r gion of the mastoid process causing a paresis of the accessory nerve. The nerve lesion had been left untreated. The patient had pain and weakness in the shoulder region and later also paraesthesia in the upper extremity because of which a scalenomyotomy had been made six years later This did not resolve the situation and two years later the scapula was operatively fixed to the spinous processes by fascial slings. The symptoms were markedly relieved by this procedure and the patient was able to continue her work during the next ten years until she crashed with her car After this accident the shoulder drop and other symptoms returned The s tuation gradually became so much worse that the patient was no longer abl to c ntinue her work. Repeated elevation of the right arm which was necessary at work, caused intractable pain and paraesthesia There was a typical shoulder dr p (Figure 3 A) with a rotation of the scapula. The active abduction of the arm was only 60 Passively there was no restriction of the movements No neurologi al signs in the upper extremity were demonstrable *Operation* on 3 September 1/ 1 The patient was able to assume her previous work 5 months after the op ration The shoulder was at the same level as the left one at rest (Figure 3 B) Some re idual rotatory malposition of the scapula was left The active abduction of the rm was full with

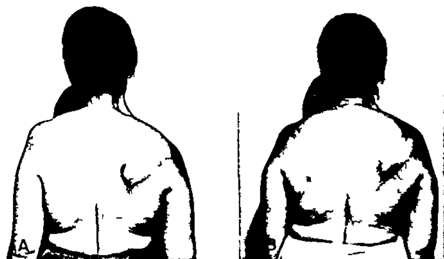


Figure 3 Case 3 Paralysis of the right trapezius treated several years previously by fixing the scapula by fascial slings Recurrence after a car accident The state before (A) and after (B) operative correction by the technique of Eden and Lange

some difficulty in between eighty and hundred degrees Active elevation of the shoulder was normal The paraesthesia had disappeared. After more strenuous days the patient had pain in the shoulder region During the time of follow up of one and a half years the situation had been unchanged

DISCUSSION

Many patients with paralysis of the trapezius muscle are able to do their work with only slight difficulty and are free of pain In these cases an operative correction is not indicated If the function of other muscles is good the loss of function of the trapezius may be sufficiently compensated It seems however that the symptoms have a tendency to become worse with time perhaps due to weakening of the muscular function and development of degenerative changes in the shoulder region This means that the operative correction in many cases may be indicated later

The upper portion of the trapezius also derives some innervation from the upper cervical nerve roots (Benninghoff 1949 Lanz & Wachsmuth 1959) Therefore the loss of function of this part of the muscle is usually not total In blunt injury which is becoming more common as a cause of paralysis of the trapezius the clinical picture may be

atypical as in in our second case. In these cases the operative procedure has to be planned individually and modified after actual needs.

SUMMARY

The results of operative correction in three cases with paralysis of the trapezius muscle are presented. The technique described by Eden and Lange was used. The time of follow up examination was one year and a half, two years and fifteen years. The result was good in all cases both subjectively and clinically. This procedure is recommended for patients in whom disabling symptoms develop as a result of paralysis of the trapezius muscle.

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HAND PROSTHESIS CONTROL VIA MYOELECTRIC PATTERNS

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It is well known that many orthopaedic appliances do not receive the immediate appreciation hoped for In fact they are frequently put away on the shelf or in the drawer and the patient manages without them This is to some extent true also for myoelectrically controlled artificial hands Undoubtedly the mechanism of rejection of such a hand prosthesis by an amputee is a complicated one involving various psychological components However it is reasonable to believe that the patient s attitude toward his new device is a result of a cost benefit analysis in which the cost is made up of technical breakdowns unsatis factory function and training time demands The benefit is calculated on the functional assistance and cosmesis

Provided a hand prosthesis is well designed technical breakdowns should be a minor source of trouble The unsatisfactory function on the other hand is a consequence of failure to solve a basic problem how to provide the patient with some of the vital hand functions he has lost The ultimate answer cannot be the simple device of today supplied with active hand opening and closing only The multifunc tional hand concept has been introduced to enhance prosthetic hand function and to make the patient more likely to accept and draw full advantage of the prosthesis

So far multifunctional hands have not been very successful none is commercially available as of now despite efforts in many countries (Rakic 1967 Kato et al 1970 Germans et al 1970 Voskoboinikova 1970 Schmidl 1971 Lymark & Mohl 1967) In addition to certain engineering problems this fact is due to the problem of how to learn to operate a complicated device quickly and efficiently

Very few reports have been presented on the theme of acquisition of skill in the operation of multifunctional prostheses, but the literature on multifunctional orthosis control gives some information Monster (1970) compared multichannel myoelectric control with mechanical movement control, concluding that it is much easier to acquire skill with movements transformed into control signals than with EMG Radonjic & Long (1970) attributed the movement superiority to the exquisite proprioception supplied in the control of movements as compared with control of individual muscle tension Kadefors & Taylor (1973) found that simultaneous operation of individual myoelectric control sites almost never occurs despite intense training Simpson (1973), using the term extended physiological proprioception has constructed a mechanical movement system for children's arm prostheses which very successfully makes use of the ease of training combined with movement control in particular when the control site is mechanically coupled to the terminal device

It is unfortunate that practical prosthesis control by body movements sometimes involves intolerable bulky transducers and transmission elements in contrast to the easily applied electrodes for myoelectric signal pick up An efficient system for myoelectric control promoting learning capability would thus be of great advantage in this situation The problem was attacked by Finley & Wirta (1967) and Taylor & Finley (1973) Pick up electrodes were placed at anatomical locations over muscles in the shoulder region of normal subjects and myoelectric levels were recorded during certain well defined arm movements An automatic method was applied to recognize the myoelectric activity patterns during the various movements With an amputee now in place of the normal subject the activity patterns evoked during movements of the phantom arm could be recognized and used for control of prosthetic arm movements with little or no training requirements

It has been known for a long time that the loss of a limb may be followed by the illusion that the limb is still there and this perceptual phenomenon has been well described (Cronholm 1951) The limb which is missing but still perceived is known as the phantom limb and the perception itself is called the phantom experience Congenital defects do not produce phantoms nor does this experience occur in children after early amputations Almost all amputees report a phantom experience which consequently must be regarded as the normal sequela of amputation

The method of using phantom sensation to facilitate or even elim

Table 1 Cause of amputations and stump length Occupation and type of prosthesis used before by the five examined amputees

Patient	Age (years)	Stump length (cm)	Amputation cause	Prosthesis used before	Occupation
A	32	17	Blasting accident	None	Painter
B	28	19	Industrial accident	Passive hand	Industrial worker
C	27	13	Blasting accident	Myoelectric prosthesis	Administrator
D	31	16	Blasting accident	Active and passive hands	Industrial worker
E	26	10	Malignant tumour	Myoelectric prosthesis	Hospital orderly

inate training has been further developed in the present project (Lawrence & Kadefors 1973 Lawrence et al 1973) We have focused our attention on the fact that the myoelectric patterns from various electrodes in the stump region show considerable individual variations due to for instance the method used in surgery A well functioning pattern recognition control system must in contrast to previous systems be able to conform to the individual characteristics of the patients

The present project is carried out using the Swedish hand (Lymark & Mohl 1967) as a display tool intended for clinical application This hand has six active movements grasp release pronation supination wrist flexion and wrist extension It is believed that this hand has enough functional capability to become beneficial provided it can be properly controlled

Summing up the present project is focused on eliminating the training burden imposed on the amputee when he is fitted with an advanced hand prosthesis The solution to this clinical problem is approached employing sophisticated digital computer techniques

MATERIAL AND METHODS

When below elbow amputees are asked to perform certain movements of their phantom hands specific muscle contractions are produced within the stump If a

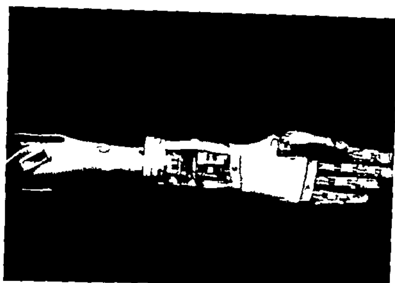


Figure 1 The Swedish multifunctional hand prosthesis with the actual socket used in the experiment

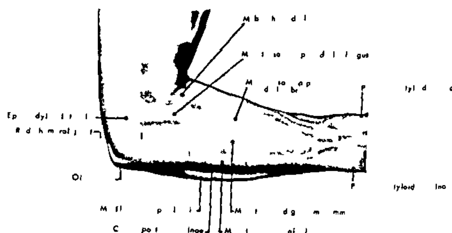


Figure 2 The dorsal view of the normal forearm and anatomical landmarks

number of surface EMG electrodes are applied around the stump different patterns of myoelectric activity can be picked up for each movement With current myoelectric control techniques it is not possible to make use of the information contained in these multi channel patterns However the use of statistical pattern recognition methods (Nagy 1968) provides a possible solution to this problem

In the first part of this investigation (Part I) the prospects of using myoelectric patterns to control movements of a multifunctional prosthesis were studied on a



Figure 3 Extensor side of a forearm stump and typical electrode positions

series of five male BE amputees They were aged between 26 and 32 years The length of the stumps and the cause of the amputations are shown in Table 1 Traumatic lesion was the cause of amputation in four cases In one case a malig nant tumour was present It is well known that most arm amputations are the result of traumatic injuries in fairly young men (Herberts 1969) The length of the stumps was measured on the dorsal side of the forearm from the tip of the olecranon

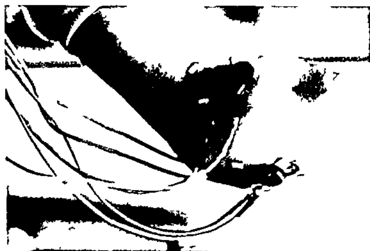


Figure 4 Flexor side of a forearm stump and typical electrode p siti ns

All five patients had a remaining phantom limb perception of their lost hand. They distinctly perceived the possibility to open and close the phantom hand and to extend and flex the wrist

The myoelectric signals from the extensor and flexor sides of the stump were evaluated according to conventional clinical electromyographic methods EMG signs of lower motor neuron lesion were found for one of the ten stump muscles only (Case D flexor stump muscle) The lesion was moderate with a reduced activity during maximum voluntary contraction However the signal was termed adequate for use in this investigation

In the second part of the investigation (Part II) one patient was evaluated with the multifunctional hand prosthesis applied The patient is identified as Case A in Table 1 The socket was made according to the conventional Munster technique and mounted to the prosthesis as illustrated in Figure 1

Electrode Positioning

By a careful clinical examination based on anatomical landmarks it is possible to identify the position of several forearm muscles (see Figure 2) All patients were asked to perform certain movements of their phantoms in order to contract the corresponding stump muscles Six phantom hand movements were performed for control of the six movements available in the prosthesis finger flexion (FF) finger extension (FE) pronation (P) and supination (S) of the stump wrist flexion (WF) and wrist extension (WE) chosen to conform to the movements of the Swedish hand

The surface electrodes were carefully placed over each individual muscle. A typical electrode pair placement is illustrated in Figures 3 and 4 In all cases one electrode pair was placed over the extensor carpi radialis longus muscle Furthermore one electrode pair was consistently placed over the flexor carpi ulnaris muscle. In three cases it was necessary to move the finger extension electrode pair from this muscle to the extensor pollicis longus muscle Otherwise these subjects could not produce a finger extension signal pattern that differed from wrist extension The position of the supinator muscle was identified from anatomical considerations Finally when the subjects were asked to pronate their forearm stumps the pronator teres muscle could easily be located by palpation Six electrode pairs could thus be arranged over six carefully evaluated stump muscle positions The accuracy with which the position of the electrodes had to be reproduced from one day to another to obtain the same myoelectric patterns depended upon the particular stump but it was observed in one case that displacements of only 2 mm could be important

Each amputee was then requested to perform six medium strength phantom limb movements FF FE P S WF and WE The subjects were instructed to relax completely before and after each contraction Graphical recordings were made during each of the six moves A typical example of the signal patterns obtained is shown in Figure 5 In some cases almost identical patterns for different movements were observed making it necessary to move an electrode with the objective of increasing the signal on the electrode dedicated to the particular movement

Technical Description

The activity patterns pertaining to particular phantom movements depicted in Figure 5 look different which implies that there is information contained in them In a mathematical sense, each one of these patterns is characterized by a set of numbers describing the average activity level in the various channels Sets of numbers can be grouped into classes (classified) using mathematical methods One such class may be referred to as finger flexion another wrist extension" and so on

Several mathematical methods are developed for classifying patterns The main problem is to find a way to separate the classes of patterns using mathematically defined boundaries having the character of surfaces Methods for computing linear surfaces hyperplanes are described by Specht (1966) Ho (1965) Anderson (1958) and Peterson (1965) In the course of the present project these methods were adapted to a digital computer to separate the EMG patterns (Lawrence et al. 1973 Lawrence 1972) The hyperplane separating the classes "A" and "B" is mathematically described by the equations

$$f_{AB}(x) = 0$$

$$f_{AB}(x) = W_o + \sum_{i=1}^{6} W_i X_i$$

where X_i in our case denotes the rectified EMG signal from site i W_i the corresponding weight factor and W_o a constant term In the case $f_{AB}(X) > 0$ the signal pattern belongs to class "A" otherwise it belongs to class B" The method is illustrated in Figure 6

The myoelectric signals were processed by means of a Grass amplifier (models 7P3B and 7DAD) which provided high pass filtering at 10 Hz cutoff amplification full wave rectification and low pass filtering of the rectified signal at 0 8 Hz After visual check of the graphic recordings the signals were fed into the analog to digital converter of the computer a PDP 15 Patterns from each one of the six hand movements as well as during relaxation were recorded and stored The time duration for recording one pattern was in all cases chosen as 5 seconds

At a later stage in the project the method for signal processing was modified in relation to how it was performed in the first period (see Table 2) The table shows that in Part II any number of data points are allowed This facility makes it possible to use several recordings of training data and superimpose them

The seven groups of training data were separated one group supposed to belong to class A" was placed in category "A" and the remaining six in category B" (see Figure 6) The weight factors were computed and a simple analysis was performed. This analysis showed how many of the data points from category "A" fell into class B" and how many of tho e from category B fell into class "A" This computation and analysis was carried out for all of the six movements so that six sets of weight factors representing the hyperplanes were generated.

Once this training phase had been finished, a computer on line classifying test was performed Real time EMG signals from the subject were then processed by the computer generated weight functions A pattern belonging to any one of the movement classes resulted in a signal from the digital to analog converter to the driving electronics of the prosthesis movement concerned

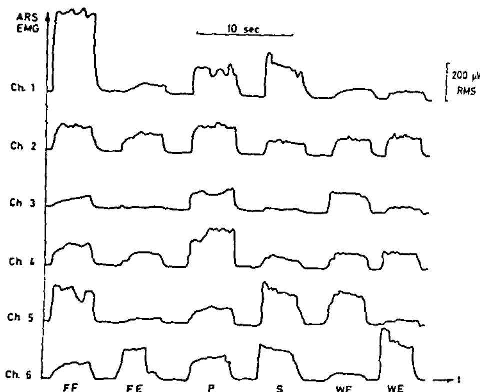


Figure 5 Amplified rectified and smoothed EMG from six electrode pairs applied on a forearm stump The patient performs six phantom hand movements (see the text)

As described above the pattern recognition procedure is performed in two main phases one training phase and one test phase (see Figure 7) The next step is to make the classification of the patterns with the computer off line The mathematical operation f(X) and the classification procedure are easily realized by means of an electronic network This network generates the function and a threshold logic unit checks whether the function value is greater than zero or not (see Figure 8) The complete network contains six channels one for each movement Every one of the processed EMG signals is fed into every channel responding with a 1 out if the pattern belongs to the class of movement of this channel otherwise the output is a 0 The channels for opposing movements are connected to one output in such a way that when both are giving a 1 the resulting output is a 0 The three outputs are then connected to the Swedish hand The way the channels are connected allows the operator to make the three bidirectional movements simultaneously

The objective is of course not to have the patient carry around a computer The method employed for the pattern recognition (Lawrence 1972) requires only linear mathematical operations and is thus easily realized in a miniaturized electronic circuit adjusted to the individual patient (see Figure 9) This circuit can be made small and lightweight it is inexpensive and easy to adapt to the patient

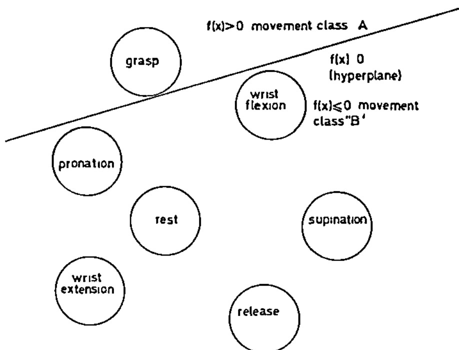


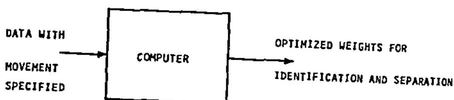
Figure 6 Schematic illustration showing the separation process In this example a hyperplane $f(x)=0$ separates grasp belonging to class A from the remaining five movements lumped in class B

Table 2 Technical details of the two parts of the investigation

	Part I (first period)	Part II (later period)
Sampling frequency	25 Hz	50 Hz
Number of data points from each pattern	9	infinite
Type of electrodes	passive	active, gain × 25

Experimental Set Up

In Part I of this investigation each subject was requested to find a comfortable position in the chair When adequate separation of the myoelectric signal patterns was obtained the subject was connected to the Swedish multifunctional prosthesis which was mounted on the bench Each subject was immediately evaluated on a set of twelve sequences of six movements in the order described above The task of



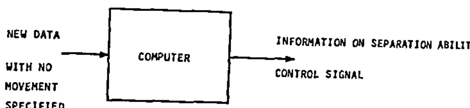


Figure 7 Pattern recognition procedure

each subject was to activate a particular motorized movement of the prosthesis from one extreme mechanical position to the other in the direction of the requested movement The total time from start command until the prosthesis reached its extreme position was registered If the task was not completed in 15 seconds the run was recorded as a failure and the next movement in the sequence was evaluated to avoid fatiguing the subject

In Part II of the investigation the multifunctional prosthesis was applied to one patient as illustrated in Figure 10 In this case the prosthesis was not controlled through the computer but through the electronic network described in the preceding paragraph. The performance of this patient for each of the six movements was evaluated in accordance with the method described above for the Part I experiments.

Thus the functions of the digital computer in the investigations were as follows

1 Record and store multichannel EMG signals
2 Calculate weighting factors for the pattern recognition network.
3 Simulate the pattern recognition network while the patient operates the prosthesis (Part I only)
4 Analyze the patient s performance.

RESULTS

Part I

In the first part of the investigation each subject was connected to the prosthesis mounted on the bench and evaluated on the six movements described above The total time for each task was registered However there was a minimum mechanical movement time for each

of the six movements FF FE P S WF and WE This minimum movement time was 1 5 1 0 2 0 2 0 0 8 and 0 8 seconds respectively In order to get a uniform measure of performance for each access the selection time defined as the total time less the minimum mechanical movement time was plotted This time represents the real time during which each patient is trying to produce the correct signal pattern by performing a natural movement with his phantom hand The selection times of the various patients and movements are presented in Table 3 In Figure 11 the mean values of each patient are depicted and the number of failures throughout the experiments is also shown

Table 3 Selection time in seconds for various movements Medians and quartiles

Case	Finger flexion	Finger extension	Pronation	Supination	Wrist flexion	Wrist extension
	3 8	1 1	2 9	0 6	0 3	0 9
A	2 2	0 6	1 0	0 5	0 2	0 6
	0 1	0.3	0.8	0 4	0 1	0 3
	5 5	1 9	0 8	0 9	1 4	0 7
B	3 5	1 0	0 5	0 4	0 8	0 6
	2 5	0 6	0 3	0 1	0 1	0 4
	3 5	3 0	8 0	3 1	2 1	0 5
C	1 8	1 2	5 7	1 1	1 6	0 3
	0 4	0 8	3 6	0 7	1 1	0 1
	3 3	0 6	0 3		1 0	2 3
D	1.3	0 2	0 2	–	0 5	1 5
	0 4	0 1	0 1		0 3	0 8
	2 1	4 7	0 9	0.8	1 3	0 4
E	1 5	3 3	0 7	0 7	1 1	0 4
	1.3	2 2	0 5	0 7	0 7	0 3

We have considered mean selection times under one second to be a very good result especially as certain patients were slow in responding to the start command In some tasks (Case A FF P Case B FE WF Case C FF FE S WF Case D FF WE Case E WF) the mean selection time and also the upper quartile were over one or two seconds but the lower quartile was one second or less These results were also considered good The subjects can find the correct patterns most of the time and a recomputation of the weights to improve the selection problem or a slight amount of training can easily improve the performance

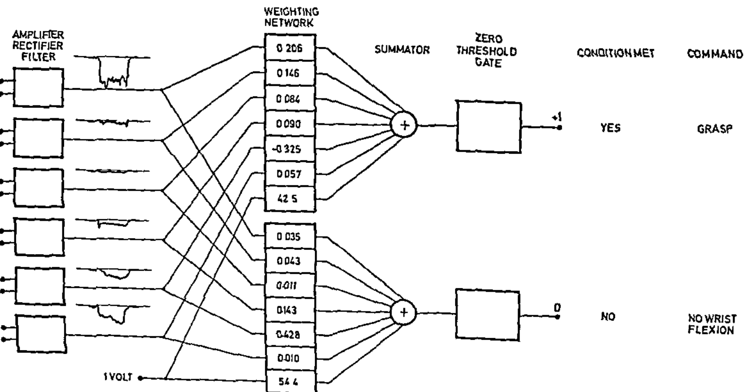

AMPLIFIER RECTIFIER FILTER
1 VOLT
WEIGHTING NETWORK
0 206
0 146
0 084
0 090
-0 325
0 057
42 5
0 035
0 043
0.011
0.143
0.428
0.010
54 4
SUMMATOR
+
+
ZERO THRESHOLD GATE
+1
0
CONDITION MET
YES
NO
COMMAND
GRASP
NO WRIST FLEXION

Figure 8 (a)

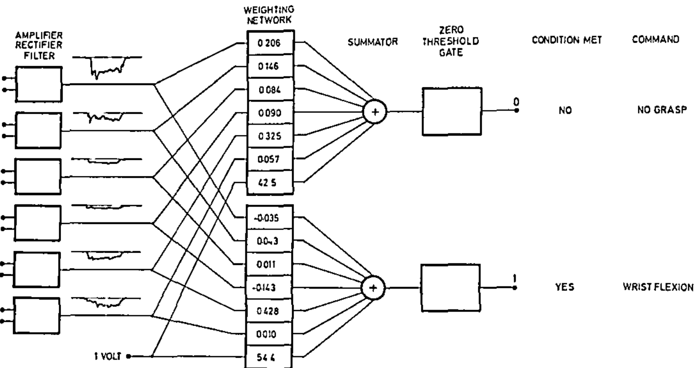


Figure 8 (b)

Figure 8 Illustration of the principle of pattern recognition control as performed with the electronic circuit shown in Figure 9 In (a) the patient intends to perform finger flexion in (b) wrist flexion The circuit responds with a command in the first case for the prosthesis to grasp in the second to flex the wrist Only the two portions of the circuit dedicated to grasp and wrist flexion are shown

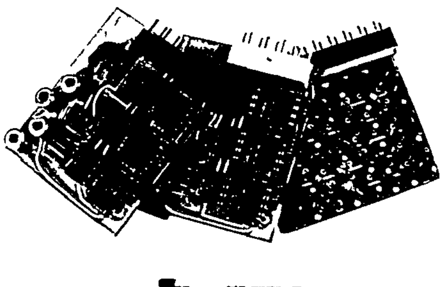


Figure 9 The miniaturized electronic circuit



Figure 10 The multifunctional prosthesis applied

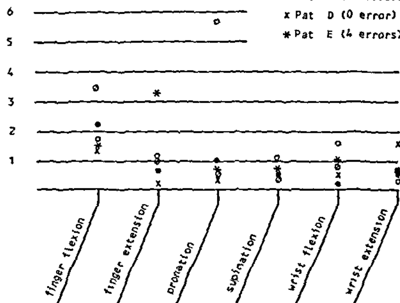


Figure 11 Medians of selection time for five patients in six movements

However in some tasks (Case B FF Case C P Case E FF FE) even the lower quartile was at several seconds containing a number of failures New electrode positions would be needed to further separate the patterns in these cases or training sessions so that better isolation could be learned Technical failure made it impossible to evaluate the supination movement of Case D

The performance of the subjects in this part of the investigation can be summarized as follows Of the 30 movements (six moves in five patients) 14 could be performed at once and a further 11 had as good prospect with minimal readjustment or training Thus 25 of the 30 movements had good possibilities for control with almost no training

Part II

In the second part of the investigation one patient (Case A) was fitted with the prosthesis as shown in Figure 10 The weighting factors were calculated on the basis of two different recordings of training

data After adjustment of the electronic network to the weights thus obtained a test run was performed Table 4 shows the results of this experiment It is evident from this table and from Figure 12 that the selection times were even shorter in this part of the investigation than in Part I Here selection times for all six movements were shorter than one second and all runs could thus be termed very good

Table 4 Mean selection time (seconds) for the various movements using miniature hardware electronics

Finger flexion	0 03
Finger extension	0 03
Pronation	0 02
Supination	0 30
Wrist flexion	0 18
Wrist extension	0 42

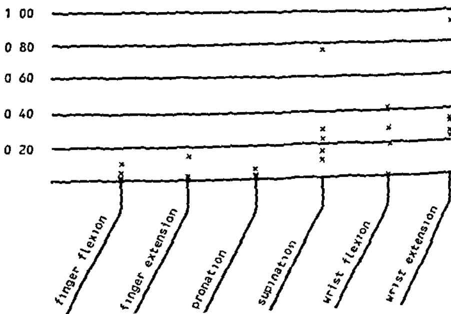


Figure 12 Selection times for one of the patients (Case A) using the electronic circuit of Figure 9 Note the expanded scale as compared to Figure 11

Several observations of interest were made during the experiments with this patient The effect of loading of the stump during bench control was tested (Lawrence et al 1973) and it was found that only minor alterations in performance were present Likewise different arm positions with the prosthesis applied did not deteriorate the controllability significantly

Evaluation of performance was made on different occasions with the same weighting factors The performance was not affected by the patient s taking on and off his prosthesis and thus the positioning of the electrodes once mounted in the socket was not crucial

In Part II the system allowed the operator to perform simultaneous movements Although this option has not been evaluated thoroughly it was observed that the patient could instantly perform combinations of movements

DISCUSSION

Efficient control of assistive devices with more than two motorized movements requires tedious and sometimes unacceptable training (Lyman et al 1964) Consequently the acceptance of the device and the functional benefit is unsatisfactory and not as good as hoped for It is therefore desirable to employ the intact neuromuscular paths of the stump when using myoelectric control of prostheses Such a system takes advantage of the natural myoelectric patterns produced when the patient desires to operate a particular hand function At the same time the patient gets a small but important conscious perception from the sensible skin when the stump muscles are performing active movements within the socket It has recently been stated by Moberg (1972) that the sensible skin is the most important factor for conscious control of position of passive and active motion and of the strength applied

The technique of pattern recognition also allows more functions to be controlled than is possible using isolated myoelectric signals from individual muscles By adjusting the electronic circuits to suit the individual amputee in contrast to other methods the differences due to individual trauma and the surgery performed are not crucial This does not mean however that the surgical technique is unimportant In our experience a careful myoplastic technique is very important in preserving the original myoelectric patterns by reducing atrophy and retraction of the muscles and thus contributes to better possibilities for control of a prosthesis

In the first part of the investigation, the placement of the electrodes was critical in a few positions Thus it was observed that displacements of 2–3 mm could be important By gaining more experience we found that this problem diminished and in the second part of the experiment we observed no alterations of the performance due to electrode displacements when the patient replaced the socket on his stump

Although six electrode pairs were applied to each patient in the two parts of this investigation it was observed that good separation of recorded data was obtained using only four electrodes This can be accomplished for instance, by excluding an electrode that carries the same myoelectric signal levels for all movements

The method used in the present investigation for classifying patterns is in a mathematical sense moderately powerful but easily realized in hardware electronics If necessary a more sophisticated method can be applied with somewhat improved recognition capability It seems however that the present method is sufficient for its purpose

As indicated in the results the system was expanded to allow simultaneous movements It was striking that this asset made the performance with the prosthetic hand look much more natural It is also likely that this improved cosmesis will enhance the patient s functional gain and acceptance

Our results indicate that control of a below elbow multifunctional prosthesis is indeed possible using myoelectric signal patterns from the stump itself It is possible to exclude a tedious training period that will demand more of the patient than he can muster physiologically or psychologically An important finding was that loading of the stump did not significantly alter the recorded data (Lawrence et al 1973) The performance with the prosthesis applied was also as good with the patient standing with his arm in various positions as it was in the sitting position A simple functional test revealed that the patient was able on the very first day without any training to take advantage of all six prosthetic movements in different tasks

However the functional benefit of a sophisticated motorized hand prosthesis for the unilateral amputee cannot be evaluated until a series of applications have been performed Ultimately the most important factor for the acceptance of these devices is to provide them with some sort of feedback signal to the sensible skin receptors for instance within the stump region

The system employed here incorporated some instrumentation for signal amplification and processing In the final system now under

development this function will be efficiently taken care of in the very pick up electrode Only the pattern recognition electronics will for the time being be housed outside of the prosthesis

The individual alignment of such a prosthesis system demands an advanced technical organization A digital computer is necessary for on line evaluation of the myoelectric signal patterns simulation control and individual adjustments of the electronic circuits To this end a centre with good medical and engineering basic resources must be provided for The equipment required for the control can however be made quite simple (see Figure 9) allowing adequate miniaturization at moderate cost The electronic hardware can easily be worn by the patient together with the battery necessary to power the prosthesis With this exception the prosthesis is self contained and applied to the patient with a conventional socket The prosthetic service can be *provided for by any skilled orthopaedic workshop used to apply commercially available myoelectric hands*

SUMMARY

In the control of multifunctional hand prostheses the lack of control sites and the demand for tedious training present difficult problems Myoelectric signal patterns from the stump muscles as evoked by movements of the phantom hand were found to be useful as control signals with the aid of computer techniques The method was successfully applied on five male amputees and will now be possible to apply in an extended clinical evaluation

ACKNOWLEDGEMENTS

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CONTINUED INVESTIGATIONS INTO THE EFFECT OF DIURETICS UPON OEDEMA OF THE HAND FOLLOWING OPERATION FOR DUPUYTREN'S CONTRACTURE BUMETANIDE LEO

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Oedema is one of the most important complications of extremity injuries and operations. This applies quite particularly to the hands because of their complicated structure and function. Only very slight oedema is required to compromise hand function for a long time or perhaps permanently. Such oedema may cause primary complications in the form of tightening of the sutures causing cutaneous necrosis and compression of vessels and nerves, and it may give rise to secondary complications, viz. posttraumatic dystrophy (Zachariae 1964).

It may therefore be of use to administer drugs which, despite their systemic effect, must be considered to exert sufficient action upon the affected extremity. However, such drugs must not have side effects so severe that the systemic risk outweighs the local advantages.

Various authors have tested a number of drugs in the attempt to reduce local oedema in extremity injuries. A survey has been published by Zachariae et al. (1970). It may be mentioned that some effect has been found with Chymar (Barclay 1960) and with Chymoral (trypsin chymotrypsin) (Lie et al. 1967, Shaw 1969).

Tanderil, claimed by some to reduce posttraumatic oedema (Miller et al. 1960, Domenjoz 1960), was studied with a particular view to hand oedema by Olesen & Zachariae (1965), who did not find a corresponding effect.

Reduction of oedema by administration of a diuretic was studied by Zachariae et al. (1970), who used Centyl Leo (bendroflumethiazide). These investigations were performed double-blind using measurements

of hand volume before and after operation for Dupuytren's contracture A significant reduction of the oedema was found in the group treated with the active substance as compared with the placebo treated group

It was reasonable therefore to try other diuretics which possibly have a more specific action

In continuation of the previous studies on the anti oedematous effect upon hands operated upon for Dupuytren's contracture and treated with the diuretic Centyl Leo *similar studies were performed in the Depart* ment of Hand Surgery of the Gentofte Hospital Copenhagen using another diuretic Bumetanide Leo The technique was exactly the same as that used previously (Zachariae et al 1970)

Bumetanide (3 n butylamino 4 phenoxy 5 sulphamyl benzoic acid) is a new high ceiling diuretic selected from a series of potent amino benzoic acid derivatives (Feit 1971) Studies on animals (Feit 1971 Østergaard et al 1972) as well as on healthy volunteers (Asbury et al 1972 Feit et al 1973) have revealed that bumetanide is characterized by an intensive and relatively short lasting diuretic and saluretic ef fect and on a weight basis 40 to 100 times as potent as furosemide Clinical investigations have confirmed that bumetanide is an effective diuretic in the treatment of oedema of different geneses without any serious side effects (Asbury et al 1972 Olesen et al 1973)

MATERIAL AND METHODS

The investigations were performed on consecutive patients undergoing operation for Dupuytren's contracture

The only selection was that all the patients were males with no other ailments The trial was double blind one group receiving Bumetanide Leo in the form of 1 mg tablets one tablet at 8 a m 2 p m and 8 p m starting immediately after the operation and continued for 10 days The other group received placebo tablets ad ministered in the same way When the patients were supplied with the tablets they also received thorough written instructions about the intake of the tablets and about only taking a maximum of about 1500 ml fluid in the form of non alcoholic beverages in the 24 hours The oedema was examined by measuring the volume of the hand in an apparatus of the type used previously and described by Olesen & Zachariae (1965) The principle of the method is to immerse the hand in water and measure the displaced volume of water

The assessments were performed on the day before the operation and on the 1st 3rd 5th 7th and 10th day after the operation However the measurements were discontinued earlier if the volume had returned to preoperative values Each group comprised 10 patients Table 1 lists the age distribution of the patients in both groups as well as complications Table 2 presents the results of the volume measurements

Table 1 All the patients were males There were no postoperative infections or nerve lesions

Case No	x/y	Age	Haematoma	Skin necrosis
1	Drug	51	—	—
2	—	49	—	+
3	—	66	—	—
4	—	53	—	—
5	—	62	—	—
6	—	52	+	—
7	—	51	—	—
8	—	67	—	—
9	—	61	—	—
10	—	63	—	—
11	Placebo	52	—	—
12	—	56	—	—
13	—	52	—	—
14	—	60	—	+
15	—	47	—	—
16	—	48	—	—
17	—	52	—	+
18	—	65	—	—
19	—	60	—	+
20	—	52	—	—

RESULTS

The material was analysed by H Engberg Pedersen statistician Dept of Mathematical Statistics, whose results were as follows

Previous investigations concerning the possible effect of Centyl Leo on the postoperative swelling of the hand have indicated that the ratio between the maximum volume of the hand, measured within the first 10 days after operation V_m and the volume prior to operation V_o that is $R = V_m/V_o$ is a convenient criterion on which to base the evaluation of the possible effect of a diuretic The logarithmic transform of R $x = \log R$, has been shown to behave as a normal deviate

Table 3 lists the 10 individual values of V_m V_o and x for each of the two groups bumetanide and placebo

Each group yields an independent estimate of the variance of x with 9 degrees of freedom f The two estimates do not differ significantly and may be combined to $s^2 = 0\ 000347$ $f = 18$ With this variance the group means are

Table 2 Volume measurements

Case No	Preop	1st day	3rd day	5th day	7th day	10th day
1	500	480	485	500	465	495
2	495	490	480	495	–	495
3	4/0	465	470	475	–	480
4	385	380	400	395	385	385
5	460	460	450	460	–	460
6	440	430	4ɔ0	490	480	480
7	460	4 0	435	450	450	485
8	440	4)0	465	460	470	47ɔ
9	420	435	415	410	–	410
10.	450	450	450	450	480	455
11	390	39ɔ	395	40ɔ	395	395
12	445	440	455	460	445	440
13	455	460	480	475	515	4/0
14	500	518	520	580	550	550
15	410	440	460	4 0	450	430
16	425	450	455	420	440	410
17	380	490	430	425	400	430
18	550	550	560	590	580	560
19	400	390	410	410	415	400
20	370	400	410	435	410	490

Bumetanide x = 0 0172 R = 1 040 95 % lmuts (1 011–1 070)
Placebo x = 0 0399 R = 1 096 95 % lmuts (1 065–1 128)
Pla/Bu R = 1 054 95 % *lmuts* *(1 012–1 097)*

Even though the confidence lmuts are rather wide due to the small number of subjects in each group the last line shows that a difference between the two treatments exists and may be of medical interest Given a mean value of 442 ml for a hand before *operation the maxi* mum swelling after operation may be calculated as

Bumetanide 17 7 ml 95 % lmuts (6 2–29 6)
Placebo 42 4 ml 95 % lmuts (26 1–59 2)

DISCUSSION AND CONCLUSIONS

From the investigations described above it is apparent that by administration of the diuretic Bumetanide Leo it is possible to reduce significantly the postoperative oedema in hands subjected to operation for Dupuytren s contracture This agrees with the results of previous studies on another diuretic Centyl Leo (bendroflumethiazide)

Table 3

Bumetanide			Placebo		
V_o	V_m	x	V_o	V_m	x
500	500	0 0000	390	405	0 0162
495	495	0 0000	445	460	0 0144
470	480	0 0090	455	515	0 0539
385	400	0 0165	500	580	0.0645
460	460	0 0000	410	460	0 0500
440	490	0 0468	425	455	0 0796
460	485	0 0230	380	430	0 0539
440	475	0 0332	550	590	0 0304
420	435	0 0151	400	415	0 0159
450	480	0 0280	370	435	0 0703
452	470	0 0172	432	474	0 0399

Table 3 lists individual values of Vo hand volume prior to operation in ml Vm the maximal volume measured within the first 10 days after operation and X the logarithm of Vm/Vo for 10 patients in each group

The difference in X between Bumetanide and placebo is statistically significant at the 95 % level

The groups of 10 patients each may seem small However as the results are statistically significant and as they fit in with previous findings this number may probably be considered sufficient

No side effects were observed This also applied to Centyl Leo in a dosage of 5 mg × 3 whereas a number of side effects occurred on 10 mg × 3 A number of the patients in the bumetanide treated group complained of the frequent and increased urination especially during the night

As for the degree of reducing the oedema Centyl Leo was found to be equally effective in the 5 mg as in the 10 mg dose In the present study, Bumetanide Leo in the doses used had practically the same effect as Centyl Leo upon the oedema

No doubt the same effect will be obtainable by almost any diuretic It is important to find one which is devoid of side effects and which may be administered in a way so that increased urination gives rise to as little discomfort as possible

Neither of the present diuretics in the doses used had any side effects and both reduced the oedema to the same extent Centyl Leo has a more protracted diuretic effect whereas Bumetanide Leo has a more rapid and time limited action As a rule the diuretic effect has

run its course in 3 or 4 hours thus causing the patients less discomfort especially after the evening dose

Concerning the indication for using diuretics to counteract post traumatic oedema of the hand the authors do not feel that it is indicated for routine preoperative administration to patients undergoing operations for Dupuytren s contracture and other similar procedures

On the other hand it seems indicated to use a diuretic—preferably Bumetanide Leo—in cases of severe hand injuries or operations causing widespread traumatization of the tissues

SUMMARY

Oedema is one of the most serious complications of hand injuries and operations Therefore constant attempts have been made to find means of reducing this oedema in addition to elevation

In a previous trial the diuretic Centyl Leo (bendroflumethiazide) was found to reduce significantly the oedema after operations for Dupuytren s contracture The present trial was a continuation of the former one but using another diuretic Bumetanide Leo

The trial was performed double blind and the oedema was assessed by a volume measurement immersing the hand in water

Bumetanide Leo in a dosage of 1 mg 3 times daily for 10 days was found to exert approximately the same reducing effect as Centyl Leo upon the oedema No side effects occurred and compared to Centyl Leo Bumetanide is more convenient as it has a less protracted diuretic effect It is emphasized that it is not planned to administer a diuretic routinely in connection with minor operations on the hand only in cases of major traumatizing operations and severe injuries Judging by the present investigations this is believed to have a beneficial effect upon the final result

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DENSITOMETRY AND 18 F SCINTIGRAPHY IN THE STUDY OF THE REVASCULARIZATION OF THE FEMORAL HEAD IN COXA PLANA (C P)

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Accepted 12 v 73

Despite the great number of publications concerning Coxa Plana since it was first described very little is known about the etiology and course of this disease Without entering further into the different opinions about the significance of trauma synovitis or growth disturbance it seems to be confirmed that partial or total necrosis takes place in the epiphysis of the femoral head probably due to failure of the blood supply (Howorth 1948 Jonsäter 1953 Goff 1954 Trueta 1957 Ponseti & Cotton 1961) The further development of C-P therefore depends on the reestablishment of vascularization

From different sides it has been shown that the increased density of the bone tissue which appears following necrosis is due to the apposition of new living bone tissue upon the old necrotic trabeculae and is thus a result of revascularization (Bobechko & Harris 1960 Hulth 1961 Bohr & Hjalmar Larsen 1965) In order to study this in relation to C-P densitometric measurements of the epiphysis of the femoral head have been made during the condensation stage Further the vascular supply has been studied in different stages of C-P through scintigraphy with radioactive fluorine

MATERIAL AND METHODS

Patients with C-P have for many years been treated with prolonged bed rest at The Seaside Hospital at Refsnæs subject to regular check ups by radiography of the hip Since 19[illegible]0 densitometric measurements have been made on the X ray photos using a calibration with ivory step wedges to determine the density of the bone structure photometrically (Mack et al. [illegible] Henny [illegible]) The step wedges were placed under the buttocks during exposure of the film to get their projections

Figure 1 Densitometer with photometer and potentiometer recorder

DENSITOMETRY
H.M C. P SIN

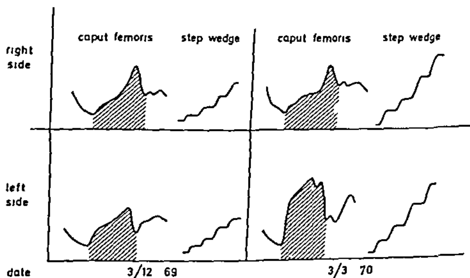


Figure 2 Densitometric measurements in a 7 year old boy with C P (case no B 19307 Table 1) Hatched area represents a sagittal section through the middle of the epiphyseal bone Ivory st p wedges shown to the right

close to the femoral head at the inside of the femoral neck as seen in Figures 4 and 6 Two identical step wedges were used one on each side to compensate for differences with regard to exposure of X rays and thickness of soft tissue The radiograph was evaluated with a photometer manufactured for this purpose so that the film was guided automatically *between a light source and a photocell* and the intensity of the transmitted light in a 2 mm broad zone was recorded with a potentiometer (Figure 1) From the absorption of the X rays the density of the bone present can be determined provided the area of bone is known

The measurements covered a sagittal section through the middle of the epiphysis and the corresponding bone area was measured with a planimeter on X ray photos in the Lauenstein projection The density of the epiphyseal bone was determined by comparison with measurements on the ivory step wedges as seen in Figure 2 and expressed in arbitrary units In all several hundred measurements of this kind were performed and through repeated determinations the accuracy is estimated to be about ± 5 per cent.

Scintigraphic investigations were made with radioactive fluorine (^{18}F) a positron emitter with a half life of 1 8 hours registering the gamma rays of 510 MeV produced through annihilation Radioactive fluorine was produced in a cyclotron at the Niels Bohr Institute by bombardment of neon with deuterons and is delivered as a sterile product in a 0 1 parts/10^3 solution of NaF An amount of 2 mc ^{18}F was given i v., corresponding to a radiation dose of 0 5 rad to the skeleton (Blaux et al 1962 Spencer et al. 1967) Scanning of the hip joints was performed one hour after the injection of the isotope using a scannomat from Siemens A/S supplied with two 5 inch scintillation crystals or an Ohio scanner with two 8 inch crystals Recordings were made with a detector both above and below the patient simultaneously

RESULTS

In Table 1 the results of the densitometric measurements on the epiphysis of the femoral head are given for 13 cases of unilateral C P admitted to the hospital during the early condensation stage The measurements on the initial X ray photos show that the density on the diseased side almost always is greater than on the healthy side and on the average shows an increase of 36 per cent which is statistically significant Following three months of strict bed rest it is seen that the density of the epiphysis on the diseased side sometimes increases a little and sometimes falls but on the average is unchanged On the other hand the density on the healthy side decreases in every case on the average by 35 per cent in relation to the initial measurements showing the amount of osteoporosis during immobilization (Bohr 1972)

Thus at the time of admission to the hospital an increased density of the epiphysis of the femoral head is present on the diseased side in relation to the healthy side and the condensation appears to be real and not apparent As the patients in the present investigation had been

Table 1 Densitometric measurements of the epiphysis of the femoral head in C-P during the condensation stage

Case no	Initial measurements		Measurements 3 months later	
	diseased side	healthy side	diseased side	healthy side
B 19307	19	14	19	10
B 19371	19	19	23	7
B 19427	21	20	19	12
B 19445	14	10	16	7
B 19490	21	15	14	7
B 19526	16	10	14	6
B 19568	23	14	26	12
B 19594	17	19	19	10
B 19599	16	9	18	7
B 19732	17	11	17	8
B 19771	22	14	20	10
B 19779	19	13	18	11
B 19887	17	11	17	9
mean value	19 ± 1 3	14 ± 1 0	19 ± 0 6	9 ± 0 6

admitted directly to the hospital and only in a few cases had been in bed for more than four days before the initial X ray photos were taken it seems unlikely that osteoporosis of the healthy side could have occurred

The scintigraphic investigations were performed in 10 cases representing different stages of C-P In a case of early condensation where

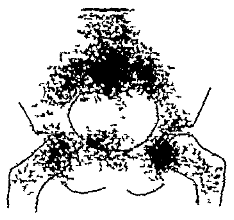
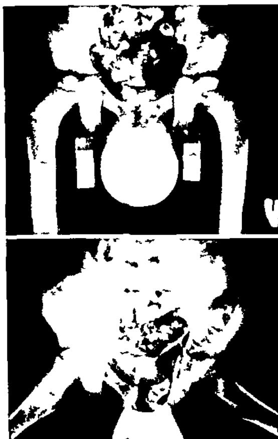


Figure 3 Scintigraphy with ¹⁸F in an 8 year old boy with C P seen during condensation stage (case no 19887 Table 1) Distinct uptake in the metaphysis and in the medial part of the left epiphysis but reduced uptake in the lateral part of the epiphysis

Figure 4 Radiographs of the hips corresponding to Figure 3



the investigation was performed immediately after admission to the hospital the scintigraph is demonstrated in Figure 3 and the corresponding radiograph in Figure 4 It is seen that there is a distinct uptake of radioactive fluorine on the diseased side especially in the metaphysis and the medial part of the epiphysis whereas the lateral part of the epiphysis shows only little uptake compared with the healthy side In four cases of late condensation with incipient fragmentation the uptake in the metaphysis and the medial part of the epiphysis was increased compared with the healthy side while the uptake in the lateral part of the epiphysis was still somewhat reduced Four cases were examined during fragmentation and showed increased uptake in the metaphysis and the total epiphysis as seen in the case presented in Figures 5 and 6 The same was true although to a lesser degree in the last case examined during restitution

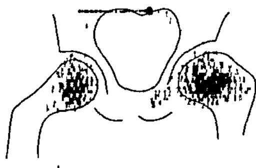


Figure 5 Scintigraphy with ^{18}F in a 9 year old boy with C P seen during fragmentation stage Increased uptake in the left metaphysis and epiphysis compared with the right side

Figure 6 Radiograph of the hips corresponding to Figure 5

DISCUSSION AND CONCLUSION

In the present investigation it has been shown that during the condensation stage *the density of the bone structure in the epiphysis of the* diseased side is increased compared with that of the healthy side At the time of the initial measurements a few days after admission to the hospital it is unlikely that the difference in density is due to osteoporosis of the healthy side and it can therefore be assumed that the bone density of the diseased side is also increased in absolute terms As shown by various authors such increase in density of necrotic bone tissue is due to *appositional bone formation* (*Bobechko & Harris 1960* Hulth 1961 Bohr & Hjalmar Larsen 1965) and therefore indicates that revascularization has taken place This is supported by the results of the scintigraphic measurements where a marked uptake of radioactive fluorine could be demonstrated early in the condensation stage It is the general opinion that the uptake of radioactive fluorine in the skeleton is due to exchange between fluorine and hydroxyions at the *surface of the apatite-crystals and measurements one hour after the* injection of the isotope preferentially correspond to the degree of vascularization (French & Mc Cready 1967 Moon et al 1968) In the work of Jonsäter (1953) biopsies from the epiphysis of the femoral head during the condensation stage showed necrosis in all 14 cases and only in 3 cases living bone was present These findings which seem to contradict the present result may represent an earlier stage of the *disease since Jonsäter states that the symptoms had occurred only* three months before the biopsies were taken whereas the densitometric measurements of the present investigation were carried out on the average four months after the onset of the first symptoms It is more likely however that the biopsies which according to Jonsäter were taken from the lateral side of the hip represent that part of the epiphysis where the uptake of radioactive fluorine was reduced

The *densitometric measurements performed after three months of* immobilization show that the bone density of the diseased side is on the average unchanged while the density of the healthy side is reduced by 36 per cent showing the amount of osteoporosis due to immobilization The fact that osteoporosis does not affect the diseased hip despite revascularization may be due to an increased rate of bone formation compensating for the general loss of bone

From the above mentioned results it may be *concluded that revas*cularization of the epiphysis of the femoral head in C-P usually has

taken place already in the stage of condensation from vessels penetrating the medial part while the vascular supply to the lateral part seems to remain reduced for a longer time corresponding to the greater involvement of this part of the epiphysis in the disease These relations may be of importance in the treatment of C P especially as regards operations which intend to promote revascularization

SUMMARY

Measurements of the bone density on X ray photos calibrated with ivory step wedges were performed on the epiphysis of the femoral head in 13 cases of C-P during the stage of condensation It was shown that the mean value of density recorded at the time of admission to the hospital was increased by 36 per cent on the diseased side compared with the healthy side After three months of immobilization the density on the diseased side remained on the average unchanged while the density on the healthy side was reduced by 36 per cent due to osteoporosis According to various authors the increase in density following necrosis of the bone is due to appositional bone formation and the present results therefore indicate that revascularization has taken place at the time of condensation This conclusion is supported by the scintigraphic investigations with radioactive fluorine showing a distinct uptake in the metaphysis and the medial part of the epiphysis The uptake in the lateral part of the epiphysis was reduced during the early condensation stage but during fragmentation and restitution the uptake was increased in the total epiphysis compared to the healthy side

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CALVÉ PERTHES DISEASE

With special reference to histological observations

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Histological examination of cases of human Calve Perthes disease *in vivo* has been described previously by Perthes (1913) Phemister (1921) Riedel (1922) Ferguson & Howorth (1934) Haythorn (1949) Jonsater (1953), Ponseti (1956) and Mizuno et al 1966) A brief summary of the conclusions drawn from the studies available is that necrosis of both bone and bone marrow may be found in the earlier stages of the disease whereas in later stages there are regenerative changes with development of more or less irregular bone masses Crushing of the trabeculae has been reported previously but this is particularly mentioned in cases where biopsy was obtained by curettage (Haythorn 1949) or bone puncture (Jonsater 1953 Ponseti 1956) It cannot be excluded that such crushing is in fact a result which is an artificial product

The present study comprises a small group of patients with Calvé Perthes disease treated with subtrochanteric or intertrochanteric osteotomy The operations were combined with opening the hip joints and as carefully as possible under the control of the eye removing a thin wedge from the anterior surface of the femoral head consisting of the articular cartilage and a small part of the ossification centre Biopsies were taken at various stages of the disease ranging from early in the initial stage to late in the fragmentation stage

MATERIAL AND METHODS

The material originates from 13 patients (11 boys and 2 girls) with radiologically verified Calvé Perthes disease Seven of the cases were bilateral three right sided and three left sided. Treatment consisted of subtrochanteric or intertrochanteric osteotomy of the femur In three of the cases an adjustment of the position of the femoral head in the acetabulum was performed simultaneously in order to obtain

Figure 1 Diagram showing that biopsy is taken as a wedge of the articular cartilage including part of the ossification centre



better contact Osteotomy was performed on both sides in one of the seven bilateral cases The age of the patients at the time of operation ranged from 3 $^3/_1$ years to 8 $^9/_{12}$ years average 5 2 years

In six cases arthrography was made in connection with the operation before the hip joint was opened After opening the joint the macroscopical appearance of the head was evaluated and a photograph taken Furthermore assessment was made of any changes in the capsule and synovial membrane and in six cases biopsy specimens were obtained from those sources The biopsy material from the head was taken with a fine chisel, a wedge shaped flake a few millimetres in breadth being taken from the anterior of the head. This contained both the articular cartilage and a small part of the ossification centre (Figure 1)

Before the operation labelling was made with Ledermycin the patients being given two injections of 150 mg intramuscularly for two days twice with an interval of 14 days The last injection was given 24 hours before the operation

In addition to the 14 biopsies from patients with Calvé Perthes disease biopsy material taken at autopsy from three children between the ages of 4 and 5 years was available as control material

Preparation

Immediately after the biopsy specimen was taken the preparation was fixed in 10 per cent formalin alcohol When large enough the specimen was divided into two pieces each containing a small part of the ossification centre Preparations for histology were prepared from the one part after prior decalcification After embedding in paraffin sections with a thickness of 5–10 μ were cut and staining was made with haematoxylin eosin and toluidine blue The other part which was available only if the specimen was big enough, was embedded in methyl methacrylate without prior decalcification after which the preparations were cut and ground down to a thickness of 50 μ These latter preparations were used for examining the result of labelling with Ledermycin using fluorescence microscopy and microradiographical examinations. Machlett A E C X ray tube (Carl Drenck) was used and the pictures were taken at a distance of 50 cm using 10 m Amp and 12 kV

The biopsy specimens from the capsule and synovial membrane were embedded in paraffin cut into sections with a thickness of 5–10 μ and stained with haematoxylin eosin

Table 1. Radiographical, microscopical and macroscopical findings

Case No.	Age (years)	Sex	Side	X-ray stage	Macroscopy	Histology
				Stage I		
1	$6\,^{9}/_{12}$	m	r	Sclerosis, slight flattening of head	Normal	Cartilage with slight proliferation in the basal part, scattered necrosis of the bone and new bone with osteoblasts
2	$3\,^{3}/_{12}$	m	r	Sclerosis, slight flattening	Normal	Cartilage with slight proliferation in the basal part, bone trabeculae with osteoblasts, no necrosis
3	8	m	l	Sclerosis, normal contour	Normal	Pronounced proliferation of the cartilage, thick bone trabeculae with necrosis in the central part and new bone with osteoblasts, islands of cartilage
4	$4\,^{5}/_{12}$	m	r	Slight sclerosis, slight flattening	Normal	Pronounced proliferation of cartilage, thick bone formation with islands of cartilage
5	$4\,^{4}/_{12}$	m	l	Sclerosis, flattening and fragmentation anteriorly	Normal	Scattered proliferation of the basal part of cartilage, islands of cartilage in the bone, no necrosis
				Stage II		
6	$3\,^{3}/_{12}$	m	l	Sclerosis, marked flattening	Normal	Cartilage with scattered proliferation in the basal part, bone nucleus cannot be assessed
7	$3\,^{6}/_{12}$	m	r	Sclerosis, marked flattening	Normal	Marked proliferation of the cartilage, endochondral ossification and osteoblastic apposition, big islands of cartilage
8	4	m	l	Sclerosis, marked flattening	Normal	Slight proliferation of cartilage, bone trabeculae without changes
9	$4\,^{5}/_{12}$	m	l	Pronounced sclerosis and flattening	Head slightly flattened	Marked proliferation of the cartilage, thick irregular bone trabeculae with islands of cartilage

Table 1 Continued

Case No	Age (years)	Sex	Side	X ray stage	Macroscopy	Histology
				Stage III		
10	$3\,^3/_1$	f	l.	Marked flattening sclerosis and fragmentation	Head slightly flattened	Slight proliferation of the cartilage, bone nucleus cannot be assessed
11	$6\,^4/_{12}$	m	l	Marked flattening sclerosis and fragmentation	Normal	Marked proliferation of the cartilage big islands of cartilage in the bone
12	$6\,^9/_{12}$	m	r	Sclerosis flattening and marked fragmentation	Head slightly flattened	Slight proliferation of the cartilage thick irregular bone trabeculae
13	$8\,^9/_{12}$	m	r	Marked flattening and fragmentation	Head mushroom shaped	Cartilage proliferation more regular than previously marked thickening of the bone with islands of cartilage
14	7	f	l	Slight flattening scattered sclerosis	Normal	Cartilage irregular but without richness of cells and mitosis bone trabeculae without changes

RESULTS

Table 1 shows that 5 of the biopsy specimens originated from the initial stages 4 from the intermediate stages and 5 from the late stages of the disease The stages were assessed on the basis of pre operation radio graphs There was moderate sclerosis and slight flattening of the ossification centre in the early stages In the intermediate stages the sclerosis and flattening were more pronounced and in the late stages fragmentation was also seen (Figures 2 3 and 4)

In 6 cases (Nos 4 7 8 9 12 and 13) where arthrography was per formed in connection with the operation it was found that the cartilage contour of the femoral head was almost normal despite the pronounced flattening of the ossification centre seen on the radiograph (Figure 6) Only in one case (No 13) was there flattening and broadening of the contour (Figure 5) This was a late neglected case in which the femoral head was also found by gross inspection to be markedly deformed (mushroom shaped) As will be seen from Table 1 the femoral head was normal macroscopically in the majority of the cases as regards



Figure 2 Radiograph from Case No 5 left sided Calvé Perthes with sclerosis showing flattening and fragmentation at the anterior of the ossification centre



Figure 3 Radiograph from Cases Nos 4 and 9 bilateral Calvé Perthes showing at right side stage I slight sclerosis and flattening of the ossification centre at left side stage II–III pronounced sclerosis and flattening



Figure 4 Radiograph from Case No 13 bilateral Calvé Perthes showing on both sides marked flattening sclerosis and fragmentation of the ossification centre

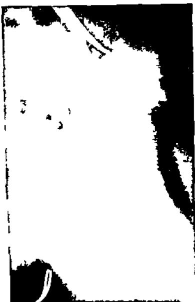


Figure 5 Arthrography from Case No 13 left side showing some flattening of the contour of the femoral head



Figure 6 Arthrography from Case No 9 showing that in spite of marked flattening of the ossification centre the contour is normal

the form and appearance of the cartilage There was only slight flattening of the head in 3 instances which were cases in a quite late stage of the disease In 3 cases there was slightly increased anteversion of the head There was nothing special to be seen at the acetabulum in any of the cases

In no case was an increase in the synovial fluid observed when the hip joint was opened In 4 cases there was some thickening of the joint capsule but the synovial membrane was always considered to be normal Histological examination of the 6 biopsies from capsule and synovial membrane showed slight hyperaemia in 3 cases but otherwise nothing abnormal When 2 of the biopsies were taken from the femoral



Figure 11 From Case No 13 Proliferation of the basal part of the cartilage more regular marked thickening of the bone trabeculae with islands of cartilage Haematoxylin eosin magnification 20 × (A) and 80 × (B)



Figure 12 Microradiograph (A) from Case No 6 child aged 3 3/12 years and (B) from normal child aged 3 11/12 showing thick bone trabeculae and new bone formation as compared with normal case Magnification 20 ×

was seen clearly at this stage together with islands of cartilage in the trabeculae (Figures 9 and 10)

In the late stages further islands of cartilage could be seen presumably corresponding to the fragmentation seen on the radiograph The cartilage was more normal basally and did not show marked irregular proliferation (Figure 11) In one case (No 14) where the femoral head was remodelled the thickness of the cartilage was somewhat irregular and there was less cell activity in the basal layer but the bone showed no changes

In none of the preparations at the different stages was there sign of collapse or crushing of the bone trabeculae

Assessment of the preparations labelled with Ledermycin showed as could be expected that the uptake was greatest subchondrally suggesting increased activity However on account of the small amount

of bone available the material was not suitable for further evaluation

The microradiographical examinations were also affected by the smal amount of bone available However it was evident that as compared with the normal material there was a marked thickening of the bone trabeculae and that these consisted mainly of newly developed bone (Figure 12) No change could be demonstrated in the thickness of the calcified zone

DISCUSSION AND CONCLUSIONS

In 1913 Perthes described the histological findings in Calve Perthes disease on the basis of a biopsy specimen from a 7 year old boy (fragmentation stage) He emphasized that this was primarily a disease which takes place inside the epiphysis since in contrast to arthritis deformans the articular cartilage was found to be normal Based on radiographical studies he considered that the epiphysis was flattened because of reduced resistance in the bone nucleus The arthrographs taken in the present study illustrate that there are no changes in the contour of the head before late in the course of the disease

On the basis of biopsy material taken by curettage Haythorn (1949) reported the finding of areas with collapse of the bone tissue and Jonsater (1953) using fine needle biopsy mentioned crushing of the trabeculae In the present study however there was no sign of collapse or crushing and thus it is possible that the changes described may have been an artificial product that occurred during the actual taking of the biopsy material

As regards the aetiology of the disease Perthes (1913) suggested that it might be a nutritional disturbance via the artery which supplies the region This is in accordance with the histological findings in the early stages of the disease since there would appear to be agreement that necrosis of both bone and bone marrow may be demonstrated (Haythorn 1949 Jonsater 1953 Ponseti 1956 Mizuno 1966)

In the present study clear signs of necrosis were found in only one of the early stages in contrast to Jonsater (1953) who found necrosis in all the stages The infrequent finding of necrosis may be due to the fact that the cases were not from early in the initial stage

Experimental studies on dogs (Mizuno et al 1966) have shown that various forms of vascular interruption of the blood supply to the femoral head produce changes resembling those found in Calve Perthes disease with partial or total necrosis By examination of dogs with

Calve Perthes Hulth et al (1962) demonstrated marked bone necrosis histologically and observed a decreased blood supply to the head by means of microangiography The basic work of Trueta (1957) on the vascular supply during the growth period reported the most interesting finding that the supply of blood to the femoral head is particularly poor in the 4–9 year age group i e the Calve Perthes age

It can be seen by comparing the histological and radiographical findings that the thick bone trabeculae found early in the regeneration stages are the explanation of the sclerosis seen on the radiographs whereas the islands of cartilage in the bone trabeculae in the late stage can account for the fragmentation

The islands of cartilage were already mentioned by Perthes (1913) He contended that these were connected with the articular cartilage or that they were new formations of cartilage or incomplete ossification The islands of cartilage found in the present study are considered to be an indication of endochondral ossification Furthermore some of the smaller islands situated subchondrally may originate from the proliferating cartilage and may be a result of the cutting technique In several of the preparations there was a little thread like connection to the articular cartilage

The articular cartilage is always quite normal on the surface (Perthes 1913) but basally there is pronounced proliferation, particularly in the intermediate stages (Jonsater 1953 Ponseti 1956)

The presence of changes deeper in the head and in the metaphysis cannot be elucidated on the basis of the present study However both Ponseti (1956) and Mattner (1968) extended their biopsy to go through the epiphyseal plate and found no changes and particularly no necrosis metaphyseally

No signs of epiphysitis as described by Phemister (1921) nor any fibrous degeneration (Riedel 1922) were found in the present study

The principal conclusion is that signs of collapse or crushing of the trabeculae in the ossification centre of the femoral head could not be observed in any of the stages of the Calve Perthes disease All the findings were presumed to be irregularly changed ossification processes as a consequence of temporary necrosis and/or arrest of the normal growth of the bone nucleus whereas the cartilage model of the head seems to be increased more or less normally Thus a deformity in the late stage seems to be caused by irregular ossification of cartilage that was not previously ossified

From the point of view of treatment it would thus be logical to

adjust the position of the femoral head in order to ensure good contact with the acetabular wall so that a spherical form can be developed during re ossification This would seem to be more important than treatment aimed primarily at relieving the weight

SUMMARY

Treatment of Calve Perthes disease by intertrochanteric osteotomy was combined with the taking of arthrographs and inspection of the femoral head Furthermore biopsy material was obtained in the form of a wedge of articular cartilage *including part of the ossification* centre from the anterior part of the femoral head

Fourteen hip joints were examined at different stages and three normal joints (obtained at autopsy) were used for comparison

Arthrography and gross inspection showed that even late in the fragmentation stage there was only little or no contour disturbance of the femoral head The joint fluid was not increased and apart from slight hyperaemia there were no changes of the joint capsule or synovial membrane

The histological examinations showed that there was only one case in the early stage with bone necrosis Slight proliferation of the cartilage basally could be seen already in the early stages In the intermediate stages marked regeneration processes were in progress There was pronounced cartilage proliferation basally and osteoblastic apposition of the bone trabeculae which were thickened and had islands of cartilage indicating endochondral ossification However some of the islands were presumed to have occurred on cutting and to have originated from the proliferating cartilage The superficial layer of the cartilage was normal but thicker than usual In the late stages there were large islands of cartilage in the bone trabeculae These were presumed to be the explanation of the fragmentation seen on the radiograph The thickened bone trabeculae were presumably the reason for the sclerosis *observed*

There was no instance of collapse or crushing of the bone trabeculae It is concluded therefore that treatment should be aimed at creating good contact between the femoral head and the acetabular wall to induce a spherical shape during the re ossification rather than a treatment which aims at a relief of weight bearing

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^{85}Sr RADIONUCLIDE SCINTIMETRY IN INFECTED TOTAL HIP ARTHROPLASTY

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Infection following total hip arthroplasty often presents difficult diagnostic problems Charnley (1972) has thus presented evidence that more than a third of infected total hip arthroplasties become manifest later than 18 months postoperatively even though in most cases the infectious agent very probably was introduced at the time of operation Hence a radiographic and/or clinical diagnosis can be made only at the end of a slow and insidious disease process It would clearly be important to establish the diagnosis infection at an earlier stage the earlier the diagnosis is established the better would be the chances to control the infection Radionuclide scintimetry offers such a method Several studies on bone infection (Bauer & Wendeberg 1959 Fellander & Lindberg 1966 Dymling & Wendeberg 1965) have demonstrated that scintimetric abnormalities may precede radiographic abnormalities for general reasons this sequence of events is probably the rule rather than the exception (Bauer 1968 Dreyer & Georgi 1972) *Now Noh (1972) and Groher et al (1972) have demonstrated cases of total* hip arthroplasty in whom infection was accompanied by high scintimetry values On this basis we decided to perform ^{85}Sr scintimetry in three series of hip arthroplasty *patients one with a normal postoper*ative course one with clinically manifest infection and one with postoperative pain but not definite infection

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MATERIAL AND METHODS

The probands of this investigation were drawn from an ongoing prospective analysis of some 300 Charnley arthroplasties operated here since March 1970 The progress of these patients is continuously analysed in terms of clinical signs and symptoms including radiography (Bergstrom et al 1973) bacteriologic immunologic and other chemical parameters The results of this study will be published elsewhere

Group 1 normal controls 17 cases

The control group was selected on the basis of the following criteria (a) pain free or insignificant pain never continuous (b) ESR less than 20 mm/h, and (c) normal radiography i e operation technically satisfactory no signs of infection, no radiolucency around the endoprosthesis nor any signs of bone formation in the soft tissues

Group 2 infection manifest 14 cases

Among 25 cases in the prospective study who had significant pain postoperatively in spite of a technically satisfactory operation, distinction was made between those who had manifest infection (Group 2) and those who had not (Group 3) Manifest infection by definition included (a) continuous pain both at rest and weight bearing (b) ESR more than 40 mm/h when not treated with antibiotics, evidence by plasmaelectrophoresis of a highly active process ESR preoperatively less than 20 mm/h and (c) at least one of the following criteria sinus formation or a progressively larger radiolucency around one or both of the components of the endoprosthesis

Group 3 postoperative pain but no manifest infection 11 cases

The cases in this category had pain intermittent or continuous at rest and/or weight bearing some had elevated ESR but none had the evidence for manifest infection as specified for Group 2 c

Scintimetry methods

Two weeks after intravenous injection of 100 μCi ^{85}Sr scintimetry was performed in two modes (1) with the detector in *fixed positions* in relation to the skeleton, and (2) with the detector *scanning* the lower pelvis and upper thigh regions including both hip joints Prior to each scan a radiogram was made with lead indicators over the hip joints and with a long focus film distance to minimize parallactic error The positions of the indicator were visible in the processed scans. The radionuclide uptake areas could thus be accurately localized in relation to the skeleton

Fixed position scintimetry was made with a scintillation detector consisting of a 7 6 × 5 1 cm NaI (Tl) crystal equipped with a reversed conical collimator of FWHM 4 cm at 5 cm and 6 cm at 10 cm from the collimator The standard positions (Figure 1) were (1) the vertex of the acetabular cup (2 and 3) the femoral shaft at ⅔ and ⅓ respectively proximal to the distal end of the stem of the endopros

Figure 1 Identification of landmarks for scintimetry A radiograph of the hip region with a lead marker was obtained at long focus to film distance For fixed position scintimetry three spots were identified (1) the vertex of the acetabular cup and (2 and 3) over the femoral shaft at ⅔ and ⅓ respectively proximal to the distal end of the endoprosthesis



thesis and (4 and 5) over the patellae The procedure was performed twice at each position *with repositioning in between The counting rates were standardized with* relation to decay and retention of tracer by division of the mean counting rates at positions 1 through 3 by the lowest at positions 4 and 5 the value obtained in this way was termed *activity*

Scan mode scintimetry (Gustafsson et al 1971 Naversten et al 1972 Moller et al 1973) was made with the crystal described above but with a coarse focusing collimator with a line spread function of about 2 cm FWHM for photons of 514 keV The detector moved at a speed of 34 cm/min and counts collected at increments of 6 × 6 mm intermittantly were transferred to an 8 k-core memory system Data were punched on paper tape which was fed into a terminal for computer processing that included an iterative deconvolution technique according to Metz At the terminal line printer outputs provided maps with iso significant count density levels presented in different symbols and an iso-countour map from an incremental plotter

RESULTS

In the normal arthroplasties (Group 1) the initially high activity dropped to an apparently stable level which was reached at about 10 months postoperatively (Figure 2) Examples of scans in this group are shown in Figures 3 and 6

By comparison with the uncomplicated arthroplasties the *infected*

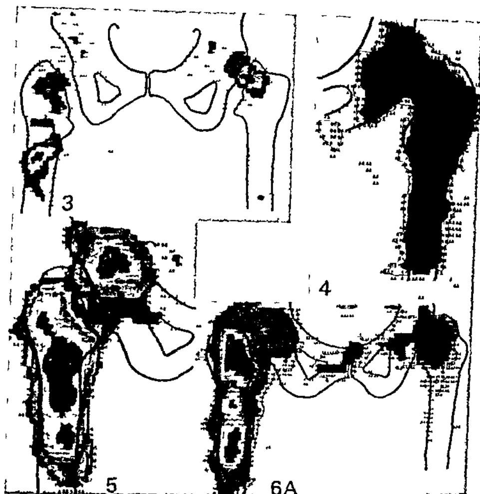


Figure 3 ^{85}Sr *radionuclide scintimetry in uncomplicated total hip arthroplasty Satisfactory clinical results after bilateral arthroplasty The scan shown here was performed 5 (right) and 9 (left) months postoperatively Dark blue and dark rose represent uptakes of 6–7 and 40–44 respectively counts/increment of 6 × 6 mm (see Figure 9 b) Intermediate colours represent stepwise additions of 3–4 counts/increment The warmer the colour the higher the uptake*

Figure 4 ^{85}Sr *radionuclide scintimetry in infected total hip arthroplasty involving both components*
Because of postoperative infection with sinus formation both components of the endoprosthesis were removed 19 months postoperatively At operation both components and the cement were loose and surrounded by pus like fluid Culture has not yet identified any microorganisms
The scan shown here was obtained a few days before removal of the endoprosthesis Note high scintimetry values both over the acetabulum and over the proximal femur corresponding to both components of the endoprosthesis

Figure 5 8 Sr radionuclide scintimetry in hip arthroplasty with late infection involving both components
Satisfactory result for 12 months postoperatively but then increasing pain ESR 50–60 mm/h and radiolucency surrounding the prosthesis Scintimetry was performed 17 months postoperatively Note very high values over both the femoral and the acetabular components and low values in the space between pelvis and femur



Figure 6 85Sr radionuclide scintimetry in patient with one uncomplicated and one infected arthroplasty
Satisfactory postoperative result in left hip *Scintimetry (A) was performed 25 months postoperatively Note moderate values over proximal femur and low values over the rest of the femur and acetabulum*
Because of pain in the lateral aspect of the right hip *wires were removed. Increasing ESR and progressive radiolucency with irregular borders around the femoral component (B) indicated an infection and the hip was explored 13 months postoperatively The femoral component and its cement were loose and surrounded by granulation tissue with pus like fluid which grew out anaerobic microorganism n t yet typed The prosthesis could easily be lifted out The acetabular component was partly surrounded by the same granulation tissue but appeared stable It was concluded that no definite infection could be confirmed here*
Scintimetry (A) was performed immediately before the endoprosthesis *was removed Note very high values over the entire femoral prosthesis and moderate values over the acetabular region*

32 months respectively Especially in the 9 month case (Figure 9) the scan showed localized high values in the region between the acetabular and the femoral components and in both cases the radiogram revealed periarticular bone formation exactly corresponding to the scan

DISCUSSION

The results of this preliminary investigation show that ^{85}Sr radionuclide scintimetry can make a clear cut distinction between normal and infected arthroplasties at a postoperative interval of 9–10 months or longer Furthermore the results obtained in Group 3 strongly suggest that in agreement with studies of other types of infectious conditions this distinction can be made even before radiographic abnormalities have become obvious in view of Charnley's (1972) observation it is highly probable that some of the patients in Group 3 will develop manifest infection However infection was not the only cause of abnormally high scintimetry values in this study periarticular bone formation non infectious in origin, was the cause of high values in at least two patients (Figure 9)

On the basis of the results presented here it is obvious that radionuclide scintimetry should have an important place in the differential diagnosis of postoperative pain in total arthroplasties In this sense this investigation confirms the general dictum that radionuclide scintimetry is particularly useful in cases of bone and/or joint pain without radiographic abnormality (Bauer 1968) However the observation that it took as long as 9–10 months until a distinction could be made between normal and infected arthroplasties decreases the potential usefulness of the method Further development of the methods used here could shorten this period of ambiguity First the number of normal controls should be sufficiently large to permit identification of statistically valid confidence limits Second the cause of variations within the group of normals should be identified periarticular bone formation is one example Third we deal here with a problem that differs in principle from the problem of identifying radiographically silent processes in normal bone for example cancer metastases or haematogenous osteomyelitis Rather the problem here is to identify a pathologic process in bone which is already involved in a highly active metabolic process viz healing following osteotomy reaming introduction of acrylic cement and the components of the endoprosthesis changes in weight bearing characteristics of the bone stock etc Inasmuch as

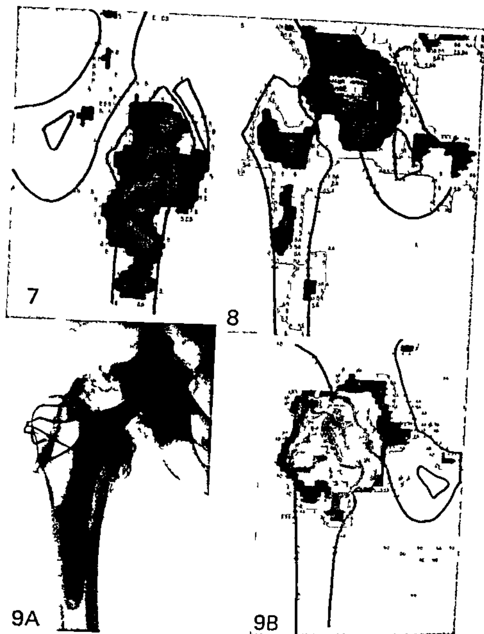
radionuclide scintimetry values represent the first derivative of the radiographic image (Figure 22 in Bauer 1968) perhaps the second derivative i e changes in the scintimetry values would provide additional information We are at present testing this hypothesis by doing repeat scintimetries on a prospective basis

As compared to other applications of radionuclide scintimetry especially as regards the appendicular skeleton the scintimetry values obtained in cases of hip arthroplasty are difficult to evaluate in this study the hip values have been expressed in terms of the lowest knee value (Danielsson et al 1963) but it may prove better to relate hip values to total body retention (Cameron 1969)

At any rate we conclude from this study that diagnosis and hence treatment of infection following total hip arthroplasty can be achieved earlier if radionuclide scintimetry is added to clinical chemical and radiographic methods Furthermore causes of pain other than infection may perhaps be excluded with the aid of scintimetry Finally the possibility of making an early diagnosis of infection involving only one of the two components may aid in limiting a surgical procedure aimed at eventually saving the arthroplasty (Figure 8)

SUMMARY

Forty two cases of the Charnley type total hip arthroplasty were subjected to ⁸⁵Sr radionuclide scintimetry at 2–34 months postoperatively Scintimetry was performed in two modes with the counter fixed over predetermined positions and continuously scanning In normal cases an initially high uptake was found to drop to a stable level which was reached some 10 months postoperatively By comparison 14 cases of manifestly infected arthroplasties had higher values significant after the initial 12 month postoperative interval In some of these cases scintimetry suggested that the infection involved only one of the two components of the arthroplasty this was confirmed at operation Also in a third group of 11 cases with postoperative pain but no manifest infection the scintimetry values were significantly higher than in the normals In two of these cases the scintimetry pattern corresponded to radiographic evidence of periarticular bone formation as a cause of postoperative pain and stiffness In at least some of the others it is probable that the elevated scintimetry values signified infection which will only later become manifest radiographically It is concluded that radionuclide scintimetry is a useful adjunct in the differential diagnosis



For colour code see caption Figure 3

Figure 7 *^{85}Sr radionuclide scintimetry in total hip arthroplasty with postoperative infection involving only the femoral component*
Because of sinus formation and other signs of infection the endoprosthesis was removed 8 months postoperatively The femoral component and its cement were loose and surrounded by a thick granulation tissue including a yellowish fluid which grew out anaerobic microorganisms not yet typed The acetabular component however was completely stable and it could be removed only with great difficulty there were no signs of infection under the cement
Scintimetry was performed immediately before the endoprosthesis was removed Note high values over the proximal femur and low values over the acetabulum corresponding to the operative finding of infection involving only the femoral component

Figure 8 *^{85}Sr radionuclide scintimetry in total hip arthroplasty with infection involving only the acetabular component*
Because of pain increasing ESR and radiographic signs of infection the right hip was explored 17 months postoperatively The acetabular component with its cement was completely loose and a thick granulation tissue with pus like fluid grew out anaerobic microorganisms not yet typed In contrast to the acetabular component the femoral component was completely stable without macroscopic signs of infection The femoral component was therefore not removed and continuous flow drainage was established After intensive treatment with antibiotics a new acetabular cup has been inserted 2 months postoperatively the patient is painfree and there are no signs of infection
Scintimetry was performed immediately before the hip was explored Note high values almost exclusively over the acetabulum

Figure 9 *^{85}Sr radionuclide scintimetry in total hip arthroplasty with periarticular bone formation*
Gradually developing postoperative pain and stiffness but normal ESR Seven months postoperatively radiography (A) showed periarticular bone formation and scintimetry (B) markedly high values in the region between the acetabulum and the proximal femur

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of postoperative pain in total arthroplasties in particular that infection may be diagnosed and treated earlier with the aid of this method and that identification of infection involving only one of the two components of the endoprosthesis may aid in attempts at surgically saving the arthroplasty

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EXPERIENCE WITH THE McKEE FARRAR TOTAL HIP REPLACEMENT

A report of 143 operations

P SALENIUS & L E LAURENT

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Total hip replacement was first performed by Wiles in 1938 in six patients (Wiles 1958 Lowy 1968) and next by McKee who performed 3 total hip replacements in 1951 (McKee 1951 McKee & Watson Farrar 1966) Finally in 1958 Charnley and in 1960 McKee & Farrar began to perform this operation regularly using methylmethacrylate to fix the components into the bone (Charnley 1960 1961) All subsequent modifications of Charnley and McKee prosthesis are fixed to the bone with bone cement whereas the Ring prosthesis (Ring 1968) is applied without cement in the bone

Total hip replacements were started at the Orthopaedic Hospital of the Invalid Foundation Helsinki Finland in June 1967 Since that time until the beginning of 1973 we have performed about 450 total hip replacements of the McKee Farrar type The purpose of this paper is to report the results of the first 143 operations performed until the end of 1970 with an observation time from 2 5 to 5 years

MATERIAL AND METHODS

The number of operations was 143 The number of patients was 126 of whom 17 w operated bilaterally The distribution of the patients is indicated in Table 1

Table 1 Number of patients and hips

	No of patients	No of hips	Bilateral op
Women	74	80	
Men	52	63	
Total	126	143	

The indication for the operation was advanced osteoarthritis of the hip with considerable limitation of mobility of the hip In such cases the result of osteotomy has been poor in previous reports (Salenius et al 1971) In some of the youngest patients the indication for the operation was rheumatoid arthritis with grave limitation of motion in the hip joint The pre operative mobility of the hip joints is showed in Table 2

Table 2 Pre operative flexion of the hip joint

Degree of flexion	No of hips
0–30	72
30–60	44
60–90	27
Total	143

All patients had weight bearing pain in the hip before the operation and in addition more than half of the patients also had pain at rest The age distribution of the patients can be seen in Table 3

Table 3 Age of the patients at operation

Years	20–29	30–39	40–49	50–59	60–69	over 70
No of hips	3	6	24	44	59	7 = 143

The youngest patient was 20 years and the oldest 76 years of age 33 patients were younger than 50 years These were cases with bilateral osteoarthritis and ankylosis or grave limitation of motion in both hips with pain at rest and on weight bearing The total hip replacement operation was then performed as an alternative to arthrodesis or Girdlestone s operation

OPERATIVE TECHNIQUE

The operations were performed with an anterolateral approach according to the technique published by McKee & Farrar in 1966 In the beginning the larger size of acetabular cup was used Later we changed to the smaller type of cup which is better fitted into the acetabulum This has been regarded as an improvement to stability and seems to diminish the risk of loosening of the prosthesis The cartilage was removed entirely from the acetabulum but the sclerotic bone under the cartilage was left in order to increase the stability in fixation with the cement It became obvious that if the sclerotic bone was removed and the cement was applied in the soft cancellous bone the fixation was not firm enough Three to four holes of about 10 mm in diameter were drilled in the acetabular roof One or two of these holes were bored through the acetabular medial and cranial wall The acetabulum was cleansed of all soft tissue Two types of acrylic cement have been used Simplex and the C M W cement Of the cups 85 were of the smaller size and 58 the larger size Suction drainage (Redivac) was applied postoperatively as a routine Sometimes the operative wound was rinsed during the operation with a

solution of antiseptics or antibiotics or an antibiotic powder was applied in the wound. Postoperative antibiotic therapy was not used as a routine. The patients were mobilised the first day after operation and partial weight bearing with crutches was allowed. The duration of the post operative hospitalization is seen in Table 4.

Table 4 Duration of post operative hospitalization

	No of hips
Less than 3 weeks	71
3–6 weeks	60
More than 6 weeks	12
Total	143

COMPLICATIONS

Table 5

Death relating to operation	2	Mortality 1.6 %
Embolism of lung	2	(1 fatal 3 weeks after op.)
Cardiac infarction	3	(1 fatal [illegible] weeks after op.)
Peroneal palsy	1	(heat damage to N. ischiadicus)
Infection	7 = 4.9 %	
Early (3 weeks–3 months)	3	
Late (5–18 months)	4	
Dislocation	4	
Early	1	
Late (4–12 months)	3	
Aseptic loosening of prosthesis	18 = 11.9 %	
Acetabular part	10	
Femoral part	6	
Both parts	2	

Infection

The bacteriology and the results of treatment of the infected hips appear from Tables 6 and 7.

Table 6

Bacteriology

Staph aureus	3
Staph albus	1
Pseudomonas	2
No fistulation	1

Table 7

Treatment of infected hips

Prosthesis removed	3
Healed temporarily with irrigation	2
Healed with antibiotics	2

Five of the patients with fistulation had irrigations with Alevaire and antibiotics (Compere et al. 1967) for a few weeks, one to four



Figure 14 The patient was operated on in 1969 The primary result was good but the patient later had pain on weight bearing

times In two of the cases the fistula temporarily closed One of the infected cases had clear clinical signs of infection 5 months after the operation but no fistulation and the infection healed with antibiotic treatment There have been no signs of infection at follow up 4 years later The other case had early infection and fistulation after operative reduction of prosthesis because of early dislocation The infection healed and had not relapsed one year after the operation when the patient died of a cardiovascular disease

Periarticular calcification

There were only 4 cases with noteworthy postoperative calcification in these series

Dislocation

The only patient who got an early dislocation had an operative reduction and a plaster for 3 weeks The dislocation did not relapse One patient got a dislocation at home one year after operation It was



Figure 1 B In arthrography 1972 the radio opaque medium goes between the acrylic cement and bone in the acetabulum The patient is waiting for reoperation

reduced and has not relapsed The third patient had had several operations before the total replacement (Judet arthroplasty twice unsuccessful fusion operations) There was extensive scarring of the soft parts which led to a habitual dislocation of the artificial joint The prosthesis was removed The fourth patient with late dislocation had sequelae after an acetabular fracture with dislocation of the hip After reapplication of prosthesis a loosening occurred of the acetabular part which was subsequently removed

Loosening of prosthesis

This complication occurred in 18 non infected cases The acetabular part went loose in 10 the femoral part in 6 and both parts in 2 cases In these series 2 screws were drilled into the roof of the acetabulum If the screws were broken it was concluded that there was loosening of the acetabular part In one case there was cranial dislocation of the whole artificial joint which recurred after reapplication In some cases

cinematography and arthrography were used in the diagnosis of loosening (Figure 1 A, B)

The greater cup had been inserted in 9 of the 12 cases with loosening of the acetabular part of the prosthesis In 7 cases the cup was situated too laterally and was not enough covered by the acetabulum

Reapplication has so far been performed in 8 cases with good results in 5 In 2 cases the loosening recurred and in one case the joint went stiff

Pain without loosening

In 8 cases the hips were painful at follow up about 3 years after the operation Loosening or infection could not be established One of these cases was operatively explored with negative findings In some of these cases there is probably a slight loosening which cannot be clinically diagnosed

RESULTS

The follow up examination was performed for the first time in 1970 and for the second time in 1972 Two patients had died during the observation period In the follow up examination a case in which there was no pain in the hip where the mobility of the hip had reasonably increased compared to the mobility before the operation and where the patient could move around without crutches or stick was recorded as excellent or good (Merle d Aubigne et al 1954) Those in which either infection or continuous pain was present and in which the mobility of the hip had not increased after the operation were regarded as poor If the patient had pain on strain but the mobility of the hips was increased and if he could move around without crutches the result was recorded as fair The results of the follow up can be seen in Table 8

Table 8 Result according to patient at follow up

	Excellent or Good	Fair	Poor	Total
1970				
No of hips	121 (86 %)	15 (11 %)	5 (3 %)	141
1972				
No of hips	108 (78 %)	13 (9 %)	18 (13 %)	139

If the results were divided into excellent and good as recommended by Lubinus (1972) then 54 of the patients were regarded as excellent

and 50 good It was observed that if the mobility of the hip was good before the operation the postoperative mobility was better It is obvious that if the hip joint has been stiff for a very long time the soft tissues have become contracted also therefore the mobility of the hip increases more slowly than in these cases The pre and postoperative mobility of the operated hips can be seen in Table 9

Table 9 Flexion of the hip

Before operation	No of hips	At follow up	
		0–60	60–100
0–30	72	24	48
30–60	40	10	30
60–90	27	2	25
Total	139	36	103

It can be seen that a flexion motion of more than 60 to 100 was present post operatively in 103 hips

DISCUSSION

In most cases infection entirely spoils the results and leads to loosening of the prosthesis Irrigation with Alevaire and antibiotics after revision is worthwhile to try before the prosthesis is removed Buchholz (1972) successfully performed reapplication in infected cases under the cover of gentamycin mixed to the cement

In this series the infection rate of 4 9 per cent is too high and only reorganisation of the hospitals operative ward is likely to decrease the infection rate There has been a substantial decrease in infection rate in hospitals where a "green house or an operating room with laminar air flow has been adopted (Charnley Lubinus Weber) The use of local and postoperative antibiotic treatment is still controversial There are reports of the decrease in the early infection rate with systematic treatment with antibiotics (Wilson et al 1972)

Dislocation can obviously be avoided with proper operative technique Patients with scarring of the muscles and soft tissues after previous operations are not very well suited for total arthroplasty However the actual postoperative procedure allowing the patient to get up from bed on the first postoperative day does not seem to increase the rate of dislocation This is important since the rate of postoperative thrombosis and embolism is reduced with early mobilisation

Loosening of the prosthesis has occurred in 18 non infected cases (11 9 per cent) This is greater than in many other previous reports (Andersson et al 1972) The operations were performed by 8 surgeons Especially in the beginning the greater cup was not placed deep enough into the socket Later the smaller cup and a head with a long stem were used in the majority of cases The cup should be placed entirely under the roof of the socket Later the number of holes bored in the socket was increased to 5–7 and at least two holes were penetrating the wall of the acetabulum In contrast to Andersson et al (1972) our opinion is that the holes increase the stability The cement was placed into the holes using the fingers or a spoon before the rest of the cement is applied (Wilson et al 1972)

A significant resorption of the bone was noted in some of the cases where the prosthesis had loosened The cement seems to have a toxic effect if the prosthesis is loose (Wilson et al 1970)

The rate of complications in these series is rather high and we think the total replacement of the hip should still be reserved for patients in the higher age group In suitable cases we still prefer to perform osteotomy which later can be converted to a total hip In young patients cup arthroplasty or arthrodesis still have their place if osteotomy is not indicated

After a series of 450 McKee Farrar replacements we are now going to try the metal polyethylen principle (the Brunswil prosthesis)

SUMMARY

In the years between June 1967 and the end of the year 1970 a total of 143 total hip replacements according to McKee Farrar were performed at the Orthopaedic Hospital of the Invalid Foundation Helsinki The number of patients was 126 17 were operated bilaterally The indication for the operation was a stiffened painful osteoarthritic hip The mortality was 1 6 per cent There were 3 early infections within 3 weeks to 3 months postoperatively and 4 late infections between 3 and 18 months postoperatively The total number of infections was 7 cases corresponding to 4 9 per cent of the entire series The cup loosened in 10 cases and the femoral part loosened in 6 cases and both parts loosened in 2 cases the total number of loosening being 18 (11 9 per cent) In 8 cases reapplication was performed with a good result in 5 cases The result of the operation at follow up (after 2 5 to 5 years in 1972) of 139 hips was recorded as good or excellent in 108 (78 per cent) cases fair 13 cases and poor 18

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LOCAL AMYLOID FORMATION IN THE HIP JOINT CAPSULE IN OSTEOARTHRITIS

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In osteoarthritis there are joint capsule changes without any specific characteristics corresponding to the findings in traumatic synovitis due partially to detritus in the joint (Hulten & Gellerstedt 1940 Roy 1967). In advanced cases there is a fibrous thickening and villous hypertrophy at times focal cartilaginous or osteochondromatous metaplasia (Sokoloff 1969).

In the course of total reconstruction of the hip done by the method of Charnley for osteoarthritis in October 1970 we found macroscopic suspicion of chondromatosis. The microscopic examination was performed by a pathologist with special experience of amyloidosis (H.E.C.) who found amyloid in the fibrous capsule.

We therefore initiated a study on the occurrence of amyloid by a systematic study of the hip joint capsules from all patients undergoing total reconstruction of the hip joint by the method of Charnley.

MATERIAL AND METHODS

From November 1970 to May 1972 total reconstruction of the hip joint by the Charnley method was performed in 60 cases with systematic investigation of the joint capsule for myeloid.

During the operation we anteriorly removed a fairly large piece of the hip-joint capsule which comprised the fibrous as well as synovial capsule. The specimen was immediately fixed in neutral formalin 10 per cent for 24 hours thereafter cut into 10–20 blocks 2–3 mm thick embedded in paraffin and cut into 6 μ slices stained routinely with haematoxylin eosin alkaline Congo red and picric acid fuchsin (van Gieson). All sections were systematically examined. In the presence of amyloid the preparations stained with alkaline Congo red show a characteristic orange red. As a criterion of the presence of amyloid we also demanded that microscopic examination of these areas in polarized light show double refraction and green dichroism. This test is specific and very sensitive. In some cases special studies were carried out (Christensen & Sørensen 1972).

Table 1. Diagnosis of hip joint disease in 32 males and 24 females

Osteoarthritis of the hip	Males 29	Females 18	Total 47	Hip Joints 51
Fracture of femoral neck with necrosis of head	1	2	3	3
Rheumatoid arthritis	–	2	2	2
Spondylarthritis (Bechterew) Gouty arthritis Seq. to Calve Perthes disease Seq. to epiphysiolysis of fem. head	2	2	4	4
Total	32	24	56	60

RESULTS

From Table 1 it is apparent that among the 60 cases studied 2 had rheumatoid arthritis, 1 spondylarthritis, 2 sequelae to Calve Perthes disease and epiphysiolysis respectively. None of these joint capsules contained amyloid. One patient with gouty arthitis had large amounts of amyloid in the joint capsule. Among 3 patients with necrosis of the femoral head after fracture of the neck, only one had moderate quantities of amyloid in the joint capsule.

Below, only the findings in the 47 patients with 51 hip joints operated upon for osteoarthritis will be described.

Table 2. Amyloid in the hip-joint capsule in osteoarthritis

	Number of Hip Joints			
	Males		Females	
Amyloid	+	—	+	—
Symptoms for less than 10 years	5	9	3	8
Symptoms for more than 10 years	9	9	0	8
Total	14 44%	18	3 16%	16
Age, 45–59 years	5	7	0	5
Age, 60–69 years	8	9	0	8
Age, 70–78 years	1	2	3	3

arthritis amyloidosis is common when the disease has lasted for more than five years In such cases amyoid occurs most often in the kidneys liver and spleen (Cohen 1968)

So far amyloid deposits in joint capsules have been reported only in myelomatosis (Lichtenstein & Jaffe 1947) However Laine et al (1955) have demonstrated amyloid in joint capsules of patients with rheumatoid arthritis With our technique we have not yet succeeded in confirming their findings

To exclude myelomatosis and rheumatoid arthritis systematic studies were carried out on 29 patients with 33 operated hips These studies comprised sternal puncture rectal biopsy serological tests for rheumatoid arthritis electrophoretic studies of serum proteins including immunoelectrophoresis investigation for Bence Jones protein and clinical examination of all limb joints In all cases myelomatosis and rheumatoid arthritis were excluded and no amyloid was found in the bone marrow or rectum with our technique In our series 9 of the 18 men and 2 of the 11 women had amyloid in the hip joint capsule 5 of the males large quantities From 43 operated hips we studied bone marrow from the femoral neck No amyloid was found None of the 47 patients of the total material had rheumatoid arthritis

Owing to the experimentally demonstrated accelerating effect of cortisone medication upon amyloid formation we investigated whether previous injections of hydrocortisone into the hip had influenced the amyloid deposition Six men and 5 women had received such injections The joint capsules of the 5 women did not contain amyloid but this was found in the joint capsules of 3 of the 6 men These 3 men had received 2 13 and 15 injections respectively The patient who had received 13 injections had small amounts of amyloid in the subsynovial tissue This localization was also found in a patient who had not received injections of hydrocortisone A few of the patients had received many injections of hydrocortisone but did not have amyloid in the hip joint capsule Thus the amyloid deposition cannot have been by injection of hydrocortisone as only 3 out of 17 patients with amyloid in the joint capsule had a history of such injections

Amyloidosis may be induced in mice by injection of chondroitin sulphuric acid (Schmitz Moorman 1968) In osteoarthritis of the hip it may be imagined that chondroitin sulphuric acid may be liberated from the cartilaginous substance by the severe cartilaginous degeneration in which the cartilage is literally scrubbed off Deposition of amyloid is closely bound up with tissue degeneration

SUMMARY

At the Department of Orthopaedic Surgery and the Institute of Pathology of the Odense Hospital Denmark biopsies from 60 hip joint capsules removed in the course of total hip joint reconstruction by the Charnley method were studied from November 1970 to May 1972 Among 51 cases of hip joint osteoarthritis 17 exhibited histological signs of amyloid deposition in the fibrous capsule after staining with alkaline Congo red and demonstration of green dichroism in polarized light Amyloid was found to be 3 times more common in males than in females There was no correlation between age duration or severity of the osteoarthritis and the occurrence of amyloid or its quantity and there was no correlation between amyloid and the possible coexistence of hyalinization or inflammation Only 3 of the 17 patients had a history of hydrocortisone injection into the joint By rectal biopsy bone marrow study serological tests for rheumatoid arthritis and serum protein study as well as clinical examination rheumatoid arthritis and myelomatosis were excluded by systematic investigation of 29 patients with 33 operated hips There were no clinical signs of rheumatoid arthritis in any case Thus the deposition of amyloid must be a purely local phenomenon perhaps induced by chondroitin sulphuric acid liberated from the cartilaginous substance in the degenerated articular cartilage Local amyloid deposits have not previously been demonstrated in the joint capsule in osteoarthritis

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EXPERIENCE WITH 79 SUBTROCHANTERIC VALGUS OSTEOTOMIES OF THE HIP

KNUD JØRRING & RASMUS MOVIN

Accepted 17 iv 73

Von Baeyer (1918) and Lorenz (1919) independently introduced the subtrochanteric wedge osteotomy in the treatment of unstable hips especially in the treatment of congenital dislocations and pseudarthrosis following fractures of the femoral neck At a later time (1925) Lorenz used the same operation in the treatment of osteoarthritis involving the hip joint

McMurray (1935) recommended a modified Lorenz procedure by which the line of weight bearing might be altered in cases of osteo arthritis of the hip viz an intertrochanteric displacement osteotomy

Pauwels (1935) used an abduction type of subtrochanteric osteotomy by which a shearing stress might be converted into a compression force

The blade plate internal fixation procedure to be used in cases of high femoral osteotomies (Blount (1943)) meant the introduction of a method by which the hip might be stabilized after surgery

Many variations of high femoral osteotomy have been described but the intertrochanteric type with or without displacement with or with out varus or valgus angulation has in recent years become the most popular procedure A fairly high percentage of non union ranging between 3 and 28 is a common feature (Rosborough & Stiles 1967 Scott 1967 Ferre & Tilling 1969)

Muller et al (1970) and Holst Nielsen et al (1972) recommended a compression type of fixation using either the ASIF compression plate or a McLaughlin apparatus by which hazards of non union might be escaped

The object of the present paper is to publish our experience in 79 subtrochanteric valgus osteotomies performed on 79 patients suffering from sequels of fracture of the neck of the femur (10 per cent of the total number of patients admitted on this account)

MATERIAL AND METHODS

During the period from 1961 to 1971 subtrochanteric valgus osteotomy was performed on 79 patients Seventy five per cent of the patients were 60 years of age or more 50 per cent being above 70 Eighty per cent were females The primary treatment of the patients is outlined in Table 1 Complications indicating osteotomy are listed in Table 2 The interval of time between onset of fracture and performance of osteotomy varied and covered from one month up to several years covering less than six months in 70 per cent of the cases

Table 1 Primary treatment of 79 cases of fracture of the neck of the femur who had subtrochanteric valgus osteotomy performed

Osteosynthesis a m Kuntscher Johansson	57
Disa nail	1
2 nails	1
Screw plate	1
Conservatively	12
McLaughlin or Jewett	6
	78
Primary osteotomy	*1*
	79

Table 2 Indication for subtrochanteric valgus osteotomy in 79 cases of fracture of the neck of the femur

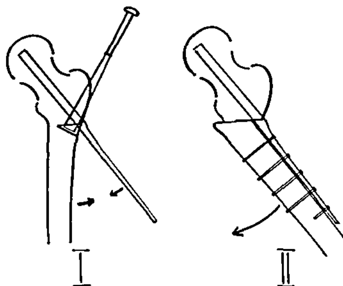
Secondary fracture dislocation	26	
Pseudarthrosis	5	36
Retarded union	16	
Nail dislocated	*15*	
Necrosis of the head of the femur	12	
Penetration of head by nail	1	
Primary wrong placing of nail	1	
Refracture during training	2	
Primary osteotomy (Pauwels III→I)	1	
	79	

By lateral approach subtrochanteric wedge osteotomy was performed as shown in Figure 1 I II The main idea was to imitate a fracture in the region, realizing that this type of fracture has a marked tendency to primary healing The method was published by Movin on the occasion of the 49oth meeting of the Danish Society of Surgeons in 1968

Throughout the first few years a Neufeld plate was used for fixation but later it was replaced by a 160 Jewett nail The patients were confined to bed for two weeks after the operation after which they were allowed to sit in a chair for another two weeks The patients had to walk in a Thomas caliper for -3 months before weight bearing was allowed.

In recent years there has been a tendency to allow weight bearing at earlier stages

Figure 1 Subtrochanteric valgus osteotomy surgical procedure



I a) A 180 or 160 nail + plate are inserted
b) A wedge is sawed out from the anterior cortex
c) The rear cortex is fractured by an osteotome

II The medial cortex is fractured the femoral shaft and the plate being collected by holding forceps the leg is abducted at the same time
It appears from the drawing that a combination of valgus osteotomy and displacement osteotomy is obtained by this procedure
The result of a lower osteotomy is a valgus position

RESULTS

Clinical as well as radiological follow up was accomplished in 63 out of the 79 cases Twelve patients died before the time of follow up two did not want to participate and one could not be traced One patient was excluded because of a fresh fracture of the tibial condyles at the time of follow up

The postoperative period of observation ranged between one and ten years averaging 3 7 years The distribution of the patients during the years is shown in Table 3

The clinical condition of the patients was evaluated and points were given according to the standard introduced by Merle D Aubigne as suggested by Movin (1957)

Table 3 Postoperative time of observation in 63 patients who had subtrochanteric valgus osteotomy performed

Time of observation	No of patients
10 years	2
9	4
8	0
7	2
6 "	4
5	4
4	10
3	15
2	13
1	9
	63 patients

Table 4 Clinical evaluation after Merle D'Aubigné of 63 subtrochanteric valgus osteotomies following fracture of the neck of the femur

		Pains		Joint Mobility		Walking capacity	
Not satisfactory	0					1	
	1			4		9	
	2	1	1	14	18	10	0
Satisfactory	3	7		16		9	
	4	18	25	6	22	14	23
Good	5	21		6		14	
	6	16	37	17	23	6	20
		63	63	63	63	63	63

An outline of this clinical evaluation is given in Table 4 from which it appears that the effect of the procedure on the patients' pains was satisfactory but the mobility of the joint and the walking capacity was not influenced accordingly

X ray pictures were taken in all cases in the antero posterior and lateral plane Healing after osteotomy was obtained in all cases

(We have done subtrochanteric osteotomy in an additional group of 23 patients with osteoarthritis of the hip and all of them also healed)

Primary union failed to occur in one case The screws of the plate broke the osteosynthesis was repeated upon which union occurred Broken screws were experienced in yet another case but even so the osteotomy healed without requiring intervention

Threatening or manifest pseudarthrosis at the site of fracture of the neck of the femur was demonstrable in 51 patients among the 63 examined Union of the fracture after osteotomy occurred in 33 cases (65 per cent) Necrosis of the head of the femur was seen in 30 of the 63 cases (48 per cent)

The rate of mortality was 1 3 per cent

The incidence of infection at deep sites was high (6 per cent) in the present series and required removal of the osteosynthetic material in all five cases Healing occurred after osteotomy in spite of the infection but the result was considerably deteriorated

In consequence of this complication our operating room conditions have been revised Nothing but clean procedures are allowed in the operating theatre in which the osteotomies are performed

CONCLUSION

The subtrochanteric valgus osteotomy is found to be a valuable measure in the treatment of sequels of fracture of the neck of the femur The effect of the procedure on the pain is especially beneficial The rate of occurrence of primary union obtained by the procedure is remarkable *The operation should never be performed in operating theatres in which* abdominal or urological surgery is otherwise performed

SUMMARY

During the period 1961–1971 subtrochanteric valgus osteotomy was performed in 79 patients suffering from sequels of fracture of the neck of the femur Sixty three patients underwent postoperatively a clinical and radiological follow up All osteotomies healed In one case reoperation was necessary to achieve union

The procedure had a satisfactory effect on the pains of the patients but mobility of the joint and walking capacity was not influenced accordingly The incidence of deep infection in the series was high (6 per cent) In consequence of this complication our operating theatre conditions have been revised

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GEOMETRIC PROBLEMS OF OSTEOTOMY

With special regard to rotation angulation osteotomy

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Accepted 17 ix 73

In the following are considered the geometric problems in osteotomy where rotation and angulation are combined

This problem may for example exist in a patient where a femoral shaft fracture has healed with abbreviation and rotation deformity It may also exist in cases of slipped femoral epiphysis In placing the osteotomy in the sub or intertrochanteric region varisation or valgisation and rotational correction can be achieved Ball and socket osteotomy has been recommended for this purpose (Campbell 1971) Southwick (1967) described a method where angulation in the a-p plane and the side projection were combined However the adaptation between the two bone cut surfaces in the described methods may be very poor with delayed healing as the result

An ideal adaptation with the greatest possible contact surface between the bone fragments is only obtained when the osteotomy is held within one plane and the displacement is made in this plane

If a cylindric stick is cut right angled to the centerline and the one fragment is turned around this line no angulation between the center lines of the two fragments will take place

If the angle between the cut plane and the centerline i e the cut inclination (Θ in Figure 1) is different from 90 and we rotate the two fragments in relation to each other around an axis vertical to the cut plane the centerlines of the fragments no longer will be the continuations of each other They will determine an angle the angulation (Ψ in Figure 2) This angle will increase with the degree of rotation It will also increase the more the cut inclination differs from 90 i e the smaller the cut inclination The correlation between the cut inclination in cases of osteotomy called the osteotomy inclination the rotation of the cylindric stick i e the bone and the developed angulation is calculated below and tabulated in Table 1

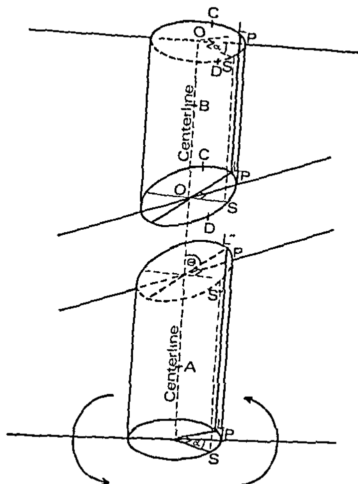


Figure 1 A cylindric stick (femur) is cut with a cut inclination (osteotomy inclination) θ The cut surfaces are ellipses the long axis of which are projected to the (right side of the) surface of the stick in L and L the short in S and S The axes are right angled to each other The planes containing the centerline and the long and the short axis respectively are projected to the surface of the stick in the lines L L and S S respectively P P P P represents the paper plane The angle α is half the wanted rotation For explanation of other letters see text

A SKETCH OF THE MATHEMATICAL CALCULATIONS

The object of these calculations is to define the correlation between the angulation the rotation and the osteotomy inclination

First we introduce our notation The variables described above angulation rotation and osteotomy angle are denoted Ψ γ and θ respectively It is necessary to introduce a new variable the cut plane rotation φ which is the angle between the two long axes of the ellipsiform cut surfaces after the osteotomy This new variable

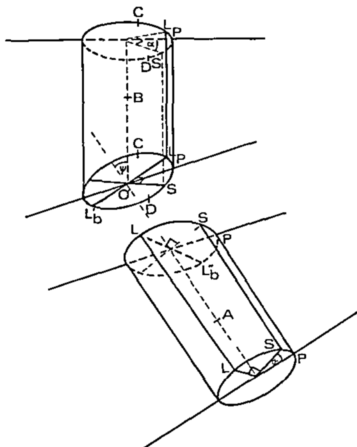


Figure 2 The lower fragment is rotated the angle 2 α. The centerlines of the two fragments are contained within the centerline plane PP'P P The long axis of the cut surfaces are marked I L_b and I L $_b$ respectively The angulation between the fragments i e between the centerlines is Ψ

will facilitate the calculations At first the correlation between Ψ φ and Θ should be found

Consider the points O A and B where O is the center of the cut surface and A and B are placed in the distance 1 (one) from O on each centerline before rotation (Figure 1) These points should be regarded as in a three-dimensional coordinate system with origo O and the centerline lying in the plane $y = o$ and the cut surface lying in the plane $z = o$ Here A and B will have the coordinates

$$A = \begin{pmatrix} \cos \Theta \\ o \\ \sin \Theta \end{pmatrix} \qquad B = \begin{pmatrix} -\cos \Theta \\ o \\ \sin \Theta \end{pmatrix}$$

Table 1 The osteotomy inclination is tabulated as a function of the wanted angulation (above) and the wanted rotation (left) The table is based on calculations made on a computer For further explanation see text

Rotation	Angulation 5	10	15	20	25	30	35	40	45	50	55	60
5	—	—	—	—	—	—	—	—	—	—	—	—
10	46	—	—	—	—	—	—	—	—	—	—	—
15	69	—	—	—	—	—	—	—	—	—	—	—
20	75	47	—	—	—	—	—	—	—	—	—	—
25	78	63	—	—	—	—	—	—	—	—	—	—
30	80	69	48	—	—	—	—	—	—	—	—	—
35	82	72	60	—	—	—	—	—	—	—	—	—
40	82	75	65	49	—	—	—	—	—	—	—	—
45	83	77	69	59	—	—	—	—	—	—	—	—
50	84	78	71	63	50	—	—	—	—	—	—	—
55	85	79	73	66	57	—	—	—	—	—	—	—
60	85	80	75	68	62	50	—	—	—	—	—	—
65	85	80	75	70	64	57	—	—	—	—	—	—
70	85	81	77	72	66	60	51	—	—	—	—	—
75	86	82	77	73	68	62	56	—	—	—	—	—
80	86	82	78	74	70	65	59	52	—	—	—	—
85	86	82	79	75	71	66	61	55	46	—	—	—
90	87	83	79	75	72	67	63	58	52	—	—	—
95	87	83	80	76	72	69	65	60	55	47	—	—
100	87	83	80	77	73	70	66	62	57	52	43	—
105	87	84	80	77	74	70	67	63	59	55	49	—
110	87	84	81	77	75	71	68	65	60	57	52	45
115	87	84	81	78	75	72	69	65	62	58	54	50
120	87	84	81	78	75	72	70	66	63	60	56	52
125	88	85	82	79	76	73	70	67	64	60	57	53
130	88	85	82	79	76	73	70	67	65	62	58	55
135	88	85	82	79	76	74	71	68	65	62	59	56
140	88	85	82	80	77	74	71	68	66	63	60	57
145	88	85	82	80	77	74	72	69	66	63	60	57
150	88	85	82	80	77	75	72	69	67	64	61	58
155	88	85	82	80	77	75	72	70	67	64	62	59
160	88	85	82	80	77	75	72	70	67	65	62	60
165	88	85	82	80	77	75	72	70	67	65	62	60
170	88	85	82	80	77	75	72	70	67	65	62	60
175	88	85	82	80	77	75	72	70	67	65	62	60
180	88	85	82	80	77	75	72	70	67	65	62	60

The rotation is now performed by rotating A the angle φ around the z axis to A (Figure 3) where

$$A = \begin{pmatrix} \cos\theta \cos\varphi \\ \cos\theta \sin\varphi \\ \sin\theta \end{pmatrix}$$

The area of the parallelogram stretched by A O B can then be determined as the length of the vectorial product of $\overline{OA}$ and $\overline{OB}$ i e

$$|OA \times OB| = \left| \begin{pmatrix} \cos\theta \\ 0 \\ \sin\theta \end{pmatrix} \times \begin{pmatrix} \cos\theta \cos\varphi \\ \cos\theta \sin\varphi \\ \sin\theta \end{pmatrix} \right|$$

$$= \sqrt{\cos^2\theta \; (\sin\; \varphi + \sin^2\theta \; (\cos\varphi - 1)^2)}$$

But the same area is determined by $\sin\Psi$ hence we get

1 $\quad \sin^2\Psi = \cos^2\theta \; (\sin^2\varphi + \sin^2\theta \; (\cos\varphi - 1)^2)$

However it was not the cut surface rotation φ that should have our attention but the final rotation γ as expressed in relation to the centerline plane i e the plane containing both centerline fragments after the angulation hence φ should be eliminated from the equation by inserting γ The relationship of φ and γ is illustrated in Figure 1 In this figure φ is the angle C O D and γ is the angle COD Regarding the coordinates in what could be called the natural coordinate system we have OC and OD with the coordinates

$$\begin{pmatrix} 0 \\ \mp \sin \dfrac{\gamma}{2} \\ \cos \dfrac{\gamma}{2} \end{pmatrix}$$

and correspondingly O C and O D with the coordinates

$$\begin{pmatrix} \cos \dfrac{\gamma}{2} \quad \cot\theta \\ \mp \quad \sin \dfrac{\gamma}{2} \\ \cos \dfrac{\gamma}{2} \end{pmatrix}$$

From this we get

$$\sin\varphi = \frac{|OC' \times OD|}{|OC'| \; |OD|} = \frac{2 \sin \dfrac{\gamma}{2} \cos \dfrac{\gamma}{2} \sin\theta}{(\sin^2\theta + \cos^2 \dfrac{\gamma}{2} \cos^2\theta)}$$

and

$$\cos\varphi = \frac{|OC \times OD|}{|OC|\ |OD|} = \frac{\cos^2\frac{\gamma}{2} - \sin^2\frac{\gamma}{2}\ \sin^2\theta}{(\sin^2\theta + \cos^2\frac{\gamma}{2}\ \cos^2\theta)}$$

By inserting this in equation 1 we find the correlation we have been looking for Even after simplification by reductions it is too complicated for manual calculations Hence we present the correlation in form of Table 1 after calculation on a computer This table may also be established (or proved) from experiments with a model

After having determined the level for the osteotomy the problem is to determine the orientation of the cut plane around the centerline The centerlines of the two fragments determine after rotation a certain

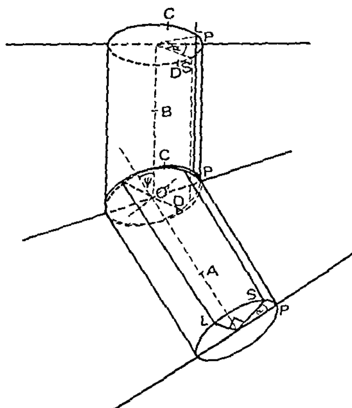


Figure 3 The cut surfaces are brought in broad contact keeping the centerlines within the PPP plane (centerline plane) Other letters see text of A sketch of the mathematical calculations

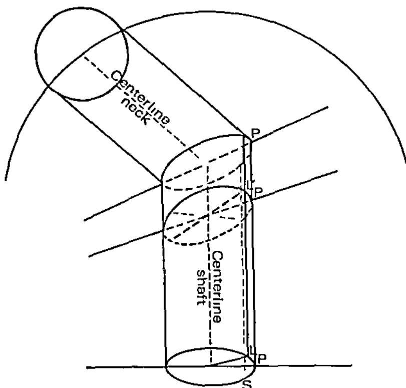


Figure 4 A model of the upper end of the femur The centerlines of the femoral neck and of the femoral shaft are kept within the centerline plane PP P (paper plane) Osteotomy is marked with the long axis of the osteotomy surface projected to L

plane the centerline plane in which the angulation takes place This plane (PP P P in Figures 1–8) divides in two equal angles the angle between the short axes of the cut surfaces Using this fact it is possible to plan the osteotomy

First the centerline plane must be fixed The projection of this plane on the outer surface of the *upper* fragment is outlined P P in Figure 1 and the angle α (= half the wanted rotation) is marked back from this line in relation to the turning direction for the *lower* fragment (in Figure 1 towards the viewer) A line S S is outlined The ellipsiform cut surface can now be characterized by having its short axis in the plane determined by the centerline and the line S S right angled to the centerline at the level where the osteotomy is wanted Marking 90 around the cylindric surface (i e around the centerline) from S S the

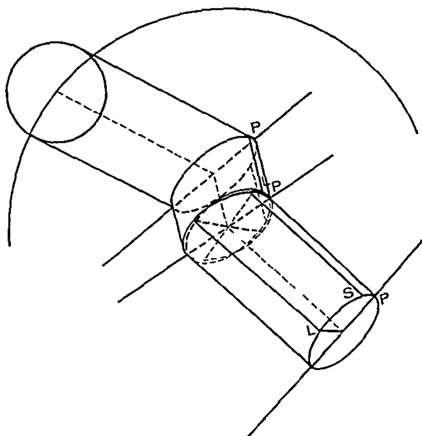


Figure 5 Rotation has been performed as in Figure 4 The centerlines are still in the plane PP P

line L L is outlined The long axis of the cut surface is contained in the plane determined by the centerline and L L The size of the angle between the centerline and the long axis of the cut surface is the osteotomy inclination θ This is found in Table 1 knowing the wanted angulation and rotation after the perfected osteotomy

For each osteotomy inclination there are two possibilities for the osteotomy plane They have the same short axis while their long axes are arranged symmetrically around the centerline In performing the osteotomy one should consider that the final apex of the angulation between the two fragments will be exactly in the middle between the summits of the osteotomy surfaces of the two fragments (in Figure 2 between the ends of the long axes marked L_b and L)

In cases of osteotomy in close relation to the trochanteric region maximal elongation of the femur is obtained when the centerline of the

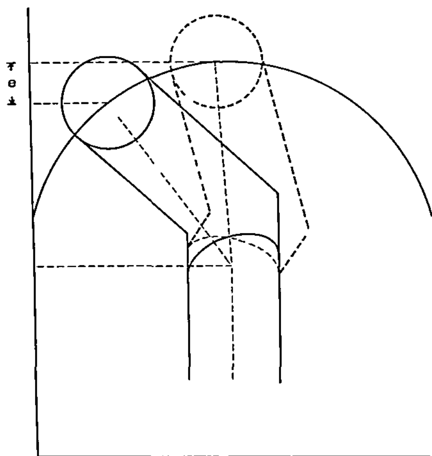


Figure 6 The elongation of the femur obtained by a subtrochanteric valgisation oesteotomy may be calculated from a drawing like this

femoral neck and the two shaft fragments are kept within the same plane (Figures 4 and 5) The elongation can be determined from the drawing Figure 6 If another direction of the collum part is wanted the angulation plane should be placed differently For example in cases of slipped femoral epiphysis a forward tilting of the femoral head is wanted together with a valgisation of the femoral neck This can be obtained by placing the angulation plane i e the centerline plane with the angulation "open forward and laterally

To illustrate how the principles of the outlined method can be used even without Table 1 the following case is reported



Figure 7 X ray of the femur from the reported case A shaft fracture has healed with 40 outward rotation of the distal fragment and 3½ cm abbreviation (March 71)

CASE REPORT

In November 1969 a 24-year old man sustained a fracture in his left femoral shaft in a car accident He was admitted to hospital and treated by insertion of a Künt scher medullary nail and cerclage wire Unfortunately the healing occurred with some shortening of the leg and outward rotation of the foot (Figure 7)

In August 1971 the patient was admitted to the County Hospital of Arhus for correctional operation A 3½ cm shortening of the left leg was found The left foot deviated outwards with an internal rotational defect of 15 and an external rotation of 100 X ray examination revealed an external rotation on the fracture site of 40

The Kuntscher nail was removed and a subtrochanteric osteotomy with derotation and valgisation was performed (Figure 8 A–B) The location for the osteotomy and the osteotomy angle were determined by cutting a model made from a wooden stick (a brush shaft) The principles outlined above were used but Table 1 was not as yet available There was good broad contact on the osteotomy site and it healed quickly The patient began weight bearing after 7 weeks

In February 1973 the internal rotation of the left hip was 10 and the external rotation 70 With the patient supine there was no difference in the position of the two feet With the patient standing a 2½ cm shortening of the left leg was found

DISCUSSION

In the referred case the rotational correction was satisfactory but the elongation was only around 1 cm of the missing 3½ cm Comparing the X rays (Figures 7 and 8 A) it is seen that the obtained angulation



Figures 8 A – B Same case as Figure 7 A subtrochanteric osteotomy has been performed with 30 inward rotation and 10 valgisation giving 1 cm elongation of the femur (August 71)

is around 10 The maximal elongation would have been obtained if the center of the femoral head had been turned right up in the elongation of the centerline for the femoral shaft i e with an angulation of around 23 However the maximal elongation would only have been around 1 5 cm compared to the obtained 1 cm and the last few extra millimeters had to be balanced against a much less acceptable position in the hip and probably more difficult osteosynthesis

In planning an osteotomy of the actual kind it must be emphasized that it is easier and safer as the first step to make a model from a wooden stick or any cylindric shaped object which can easily be cut in different angles The more detailed determination of the osteotomy-location and angulation must be determined from the wanted effect on rotation angulation and hereby elongation The further down below the intertrochanteric region the osteotomy is placed the lesser is the elongation effect

Whether it should be preferred to determine the osteotomy inclination by the calculations in Table 1 or by means of experiments with a model made from a wooden stick is up to the surgeon

SUMMARY

The problems of osteotomy where rotation and angulation and even elongation are wanted are treated clinically and mathematically The work is especially concerned in osteotomies in the trochanteric region where an angulation will be able to change the steepness of the femoral neck

Instructions for a simple osteotomy making alterations possible in all directions are outlined in detail The outlined method gives the best possible conditions for healing of the osteotomy

By means of a computer calculated table the osteotomy inclination can be determined when the desired angulation and rotation is known

Finally a case is reported where a femoral shaft fracture had healed with shortening and outward rotation of the foot It was treated by the described method

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THE KNEE IN PATIENTS WITH HIP JOINT ANKYLOSIS

Clinical Survey and Bio mechanical Aspects

M Foss Hauge

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In patients with hip joint ankylosis the ipsilateral knee has a typical clinical appearance (Hauge 1963) The condition has no special name or designation The term coxitis knee (c k) has previously been used in coastal hospitals for patients confined to bed for a long time due to tuberculous coxitis The condition has nothing to do with hip infection but for practical purposes the abbreviation *c k* will be used in the present paper

When patients as well as doctors reflect on the drawbacks of an ankylosed hip joint they are primarily preoccupied by the suspected *increased stress and strain on the spine Very few consider the conse* quent pathophysiology of the knee It has been mentioned briefly in some publications (Agerholm Christensen 1942 Karlen 1944 Ducroquet 1951) but the author s work from 1963 appears to be the first publication of clinical material The present is a continuation of this study based on a larger number of patients and a more detailed anal ysis of the material

MATERIAL AND METHODS

The series comprises 200 patients with unilateral operatively arthrodesed hips The primary cause of the hip lesion is of no significance in the development of c k., and will thus not be further commented upon

In accordance with criteria used in the selection of the patients two prerequisites were essential

1 There had to be *bony* union of the hip in all cases with trabeculae crossing the resection space and transformation of bone architecture corresponding to the new stresses (Figure 1)

2 No pathological changes of the knee in question should be found *before* the hip operation

The observation period ranged from 8 to 32 years mean 22 years, counted from the time when the hip joint was found to be ankylosed clinically and radiographi

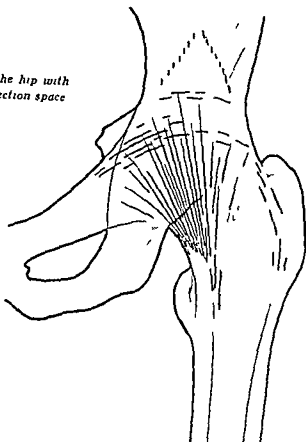


Figure 1 Bony union of the hip with trabeculae crossing the resection space

Drawing from a radiograph

Table 1 The series—age and sex distribution

Age (years)	Number Men	Women	Total
<30	4	3	7
30 – 49	23	18	41
40 – 49	29	26	55
50 – 59	33	30	63
60 – 69	12	13	25
>70	4	5	9
Total	105	95	[illegible]00

cally (usually 4–5 months after the operation) up to the time of the follow up examination This took place during the years 19[illegible]0–19[illegible]

The age of the patients at the time of follow up ranged from [illegible]2 to [illegible]3 years, mean 52 years (Table 1)

The clinical examination has proceeded exactly along the same lines as detailed in the previous publication (Hauge 1963) This also applies to the radiological criteria Particular attention has been paid to factors that may lead to erroneous evaluation of the radiographs *All* the reported findings are based on comparative examination with the other sound knee.

RESULTS

Signs – Table 2

Table 2 Clinical features of the knee in patients with ipsilateral hip joint ankylosis

	No	per cent
Change of contour	190	95
Genu valgum	102	51
Genu varum	36	18
Backward subluxation	44	22
Outward rotated position	78	39
Increased rotation ability	130	65
Instability—sagittal plane	98	49
Instability—frontal plane	192	96

1 *Change of contour* (Figure 2)—190 patients The knee appeared to be narrower the bone contours were more marked and the whole joint impressed as being smaller than the opposite knee To a certain extent this may have been an optical illusion as the changed contour of the knee was partly caused by atrophy of m vastus lateralis and even to a greater extent of m vastus medialis in the lower part of the thigh (the atrophy being estimated by measuring the thigh girth 15 cm above the knee joint)

In 20 patients the affected knee appeared more bulky than the sound one Sometimes the swelling was caused by accumulation of fluid in the joint probably as a result of synovitis following repeated minor traumas or abnormal strain of the knee In some of these patients there was a tendency to oedema of the entire limb due to impaired circulation

2 *Genu valgum* i e an increased physiological valgus—present in 102 patients—ranged from a few degrees up to 15 mean 8 The investigation showed *no* significant correlation between the valgus position of the knee and the degree of abduction of the ankylosed hip (see Comments and Discussion)



Figure 2 Typical appearance of a "coxitis knee on the right side

3 *Genu varum* (36 patients) ranged from 2–3 to 12 mean 7 It was not possible in these patients to find any relation between the varus position of the knee and that of the ankylosed hip in the frontal plane

4 *Backward subluxation* of the leg in relation to the thigh was found in 44 patients

5 *Outward rotated position and/or lateral displacement of the leg in* relation to the thigh was present in 78 patients (estimated with knee fully extended)

6 *Increased ability to passive rotation of the joint* is connected with the outward rotated position of the leg This sign was present in 130 patients

The examination is carried out with the patient lying prone the knee flexed 90 and the ankle joint fixed by maximal dorsiflexion of the foot The extent of rota

tion is judged by projection of the inner margin of the foot on to the bed where an angle measurer has been placed.

The investigation shows that the *lateral* tibial condyle slides over the lateral femoral condyle On the medial side there is rotation movement only the axis of rotation thus being on the medial side of the knee

7 *Instability—sagittal plane* (anterior and/or posterior glide) was found in 98 cases The anterior cruciate ligament is lax when the knee is flexed at about 60 the posture in which this sign is usually tested Thus a *moderate* anterior glide is not necessarily pathological However in 98 *of the patients there was an increase of the glide compared to* the healthy knee

In this series a posterior glide was a more frequent finding than an anterior the ratio being 5 to 3

8 *Instability—frontal plane (with the knee in neutral position)* was observed in 192 cases This is one of the most characteristic and constant findings in c k but in 8 cases even the most scrupulous examination failed to reveal any sideward instability A meticulous mode of procedure preferably with the femur fixed in a special frame (Hauge 1963) is required Normally medial and/or lateral movements cannot be brought about in a fully extended (hyperextended) knee

There was a tendency to correlation between this finding and prolonged preoperative immobilization but this parallelism was not significant There was no connection between degrees of side to side mobility and time elapsed since bony union On the other hand there was a definite preponderance of sideward instability in patients who had their hip ankylosis before growing up A preponderance of lateral as opposed to medial mobility was regularly found i e it was more *often* possible to press the leg (passively) into a varus (adducted) than into a valgus (abducted) position

Other signs such as reduced lateral mobility of the patella reduced active and passive flexion and/or extension of the knee were likewise observed These findings were not constant however and are not due to the hip ankylosis as such

Symptoms

Very few patients complain about knee trouble and many hardly give their knee a thought until lateral instability develops 40 patients had noticed some degree of instability in the knee *when walking* and 32 had mild knee ache Another 6 patients had more regular and in

part quite severe knee pains In these radiographs revealed considerable osteoarthritis (see below) A fairly large number of patients—48 in all—complained that the knee had become distorted by which they mostly meant a displacement to valgus position However their troubles were of a cosmetic rather than functional nature

A few patients occasionally experienced slip in the knee others complained of ache after sitting with the knee maximally flexed for longer periods (a finding that may be more normal than pathological) 25 patients stated that the actual knee was weaker than the other and tired more easily but just as many claimed that the opposite was the case that ever since the operation increased strain was put on the contralateral knee which more easily tired

Radiographic findings—Table 3

Radiographs revealed *osteoporosis* in all patients It might be slight or pronounced but was always present even in patients in good physical form as illustrated by the following example

The radiograph (Figure 3) was taken 2 years after an 18 year old boy developed ankylosis of the hip by arthrodesis He was confined to bed for two weeks preoperatively and full weight bearing was not allowed for 4 months after the operation He had always been a keen athlete and had tried to restitute the limb maximally after the operation The osteoporosis was, however unmistakable

Table 3 Radiological findings of the knee in patients with ipsilateral hip joint ankylosis

	No	per cent
Osteoporosis	00	100
Osteoarthritis	128	64
Genu valgum	110	[illegible]
Genu varum	34	17

Radiographs taken at regular intervals following ankylosis of the hip show that in c h. the osteoporosis progresses to some extent during the first 2–3 years but after that time there is no demonstrable progression A patient with ankylosis of the hip of 20 years standing will not ordinarily show more osteoporosis than someone with an ankylosis of 5 years' standing

The present investigation confirms also the author s previous *find*

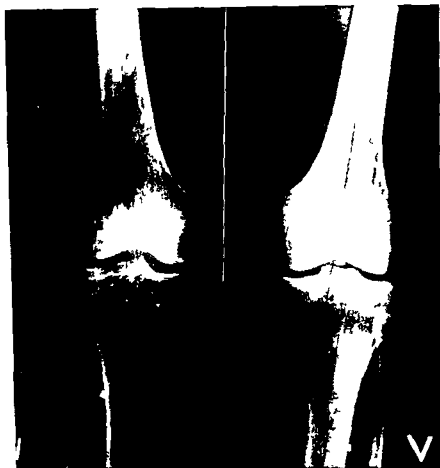


Figure 3 *Radiograph of the knees—same patient as in Figure 2*

ings (Hauge 1963) that protracted bed confinement prior to the hip joint ankylosis usually leads to a high degree of osteoporosis

Osteoarthritis is a more frequent finding in the e k than in the contralateral knee A total of 128 patients had osteoarthritis either in the actual knee alone or in both knees but preponderantly on the ankylosed side There was no definite relation between duration of the hip joint ankylosis and degree of osteoarthritis although a *tendency* to more marked osteoarthritis in patients with hip joint ankylosis of long standing was traceable However the series includes some patients with hip joint ankylosis of more than 30 years standing presenting

no demonstrable signs of degenerative changes of the knee 42 patients had developed osteoarthritis in the contralateral knee

Genu valgum and *genu varum* were demonstrated radiographically to approximately the same extent as in the clinical examination

COMMENTS AND DISCUSSION

C k is characterized by its marked objective signs but rather moderate symptoms The condition is due to the ankylosed hip joint with the following altered muscle function of the lower limb, and altered mechanics of the knee in standing and walking i e there must be a non physiological strain on the knee joint

Firstly a pathological rotation in the knee joint occurs during gait Normally, with two mobile hips rotation of the pelvis in the transversal plane takes place to a variable degree during the stance phase In patients with an ankylosed hip this causes a rotational strain on the knee in that part of the stance phase when the foot is locked to the ground Previous clinical studies have shown that the pelvic rotation during gait has no provable effect on the ankle and foot joints (Hauge 1963) It is possible that pelvic tilt (in the frontal plane) during gait varying from one individual to another adds to this abnormal effect by producing sideward bending movements of the knee

Secondly the strain on the knee due to the body weight will be altered in unilateral hip joint ankylosis

In standing position with two mobile hips the body weight is shared equally by both limbs and as the mechanical axis passes through the middle part of the knee joint the force acting on the knee will have no tendency to varus or valgus bending

Standing on one leg the plumb line will pass medially to the knee joint and thus have a varus bending effect (Exceptions are when the trunk is tilted more sideways thus making the plumb line pass through the hip and knee joint or even outside the joints) But this effect is counterbalanced by the muscle force and ligaments on the lateral side

During gait the line of action will pass medially to the knee joint but the varus bending effect will vary throughout the whole stance phase in correspondence to the changing length of the lever arm

In unilateral hip ankylosis part of the head -sometimes also the neck—of the femur is damaged either primarily or due to the operation causing the mechanical axis to fall on the lateral side of the knee joint

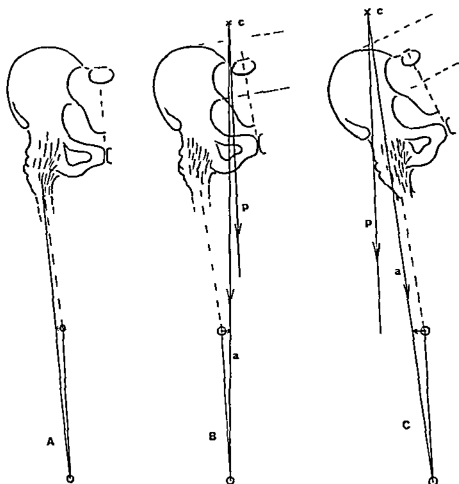


Figure 4—see text
a = line of action p = plumb line c = centre of gravity

Standing on both legs the body weight will now tend to cause a valgus angulation of the knee (Figure 4 A)

Standing on one leg and during the stance phase (single support) the force acting on the knee depends on the position of the ankylosed limb In *moderate* abduction the lever arm from the plumb line and from *the line of action* is reduced (Figure 4 B) and thus the varus bending effect on the knee joint should diminish On the other hand the effect of the valgus promoting muscles such as m tensor fasciae latae is also reduced (Hauge 1963) When the abducted position of the

hip is more marked (Figure 4 C) the line of action will probably pass laterally to the knee while walking thus causing a valgus strain on the knee

If the limb is ankylosed in a moderately adducted position up to 4 or 5 the weight of the body will have the same effect on the knee joint, but greater adduction will theoretically represent a varus bending influence on the knee

A high frequency of pathological valgus of the knee joint would therefore be expected Indeed the investigation showed a preponderance of valgus as compared to varus positions but no convincing relationship to the different positions of the ankylosed hip in the frontal plane What factors are decisive in this respect is impossible to state Nor do we have any exact knowledge regarding the centre of body gravity in the different hip positions the flexibility of the spinal column and hence its capacity to compensate the static scoliosis or the consequences of the reduced pull from the hip muscles This problem can only be solved through biomechanical analysis with adequate measuring instruments

Lastly substitutional movements of the affected lower limb undoubtedly contribute to the instability of the knee joint Patients with an ankylosed hip expose the knee joint to an extreme stress in certain situations as a substitute for a movable hip for instance when putting on shoes and stockings or when sitting with the foot and leg in forced outward rotation or valgus position Forcing the leg passively into valgus position and abnormal outward rotation increases the instability in the transversal and frontal planes

SUMMARY

An account is given of the typical clinical changes of the knee joint in patients with unilateral ankylosed hip joint on the basis of 200 examined patients

The objective findings in the knee were change of contour (95 per cent) genu valgum (51 per cent) genu varum (18 per cent) posterior subluxation of the leg (22 per cent) increased outward rotated position of the leg (39 per cent) increased rotatory ability (65 per cent) instability in sagittal plane (49 per cent) instability in frontal plane (96 per cent)

Radiographic findings Osteoporosis (100 per cent) and osteoarthritis (65 per cent)

The symptoms were surprisingly inconspicuous

The aetiology and pathogenesis of the above findings are discussed

The three main reasons for the pathological changes are

1 Abnormal rotation of the knee joint during ordinary walking
2 Abnormal distribution of the body weight on the condyles of the knee joint and reduced effect of the knee stabilizing muscles
3 Forced passive movements of the knee (during daily activity) increasing the instability primarily caused by 1 and 2

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EXPERIMENTAL OSTEOARTHRITIS OF THE KNEE IN RABBITS INDUCED BY ALTERATION OF THE LOAD BEARING

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Numerous experimental methods for inducing degenerative changes of the articular cartilage in animals have been described Only in a few cases have attempts been made to obtain conditions which encourage the development of a slowly progressive degeneration analogous with the predisposing factors known from clinical work (Hulth et al 1970) It is generally agreed that abnormal mechanical conditions predispose to degenerative changes in the misloaded joint

The aim of the present work was to investigate whether it is possible experimentally by means of valgus angular osteotomy of the tibia in rabbits to induce degenerative changes in the cartilage in the knee joint analogous with osteoarthritis in man

MATERIAL AND METHODS

Six adult rabbits weighing 3 2 to 3 5 kg were used for the experiments

Operative procedure

Observing sterile precautions and under Fluothane anaesthesia preceded by 0 5 ml Combélene i m osteotomy was performed on the left tibia The operation was made by means of medially arched incision and the proximal area of the tibia was laid open subperiostally Transversal osteotomy was then performed by sawing just distal to the tibial tuberosity and at the same time a small wedge was removed laterally from the bone with its base resulting in a valgus position of the tibia of approximately 30 The rudimentary fibula was partially resected. The position was fixed with a five hole plate with four screws prior to fixati n the plate was bent to make it conform to the valgus position The wound was flushed with Ne bacetine and closed with nylon in fascia and skin No other immobilization was made except the internal fixation There were no postoperative complications.



Figure 1 Radiograph from case 13 immediately after the operation illustrates osteotomy of the upper portion of the tibia with 30 of lateral angulation Fixation with a plate and 4 screws

The position was controlled radiologically post operatively (Figure 1) and during the investigation period radiographical control took place fortnightly

The animals were killed 10 to 12 weeks after the operation In continuation of the killing microangiography was carried out with Micropaque containing Indian ink through the abdominal aorta on the heparinized animal. The hind parts of the animal were fixed in 90 per cent alcohol which was replaced after 24 hours by 40 per cent alcohol

The specimens were evaluated macroscopically with regard to changes of the components of the knee joint especially the cartilage and the valgus position was measured

Specimens

Histological specimens were made from six cartilage bone blocks from each knee joint as shown in Figure 2 Specimens from the unoperated side were used for comparison Pieces A and B were from the medial and lateral tibial condyle respectively and pieces C and D from the medial and lateral femoral condyle Specimen F is the patella and E (consisting of bone only) was included in order to study whether the osteotomy had healed histologically The specimens were embedded without previous decalcification in methyl metacrylate containing Plastoid N and afterwards cut by Jung microtome into sections with a thickness of 5 μ From each



Figure 3 Articular cartilage from the left lateral femoral condyle (case 15) 10 weeks after the osteotomy Illustrates fibrillation flaking and clefts in the superficial layer Haematoxylin eosin Magnification × 18?

exactly Knock knee and bowleg deformities are reported as static causes of an increased stress on the knee joint resulting in osteoarthritis on the side to which the knee is turned (Ory 1961)

Even in cases of moderate degrees of valgus or varus angulation, there is a considerable increase of the load on the exposed partial joint cavity and consequently of the compressive force (Marchin et al 1963) That increased stress induced by compression causes degenerative changes of the cartilage has been proved experimentally (Salter & Field 1960 Thompson & Bassett 1970)

Clinical reports describe osteoarthritic changes occurring after shorter or longer periods of displacement corresponding to the knee condyle which is most stressed (Jackson & Waugh 1961 Coventry 1965) On the basis of a follow up of 85 knee osteotomies for osteoarthritis with axis displacement Cauchoix et al (1963) reported that the radiological



Figure 4 Slight fibrillation in the superficial layer and derangement of the cell columns of the cartilage from the left lateral tibial condyle 10 weeks after the operation (case 14) Haematoxylin eosin Magnification × 140

picture had not changed and that the operation seemed to have stopped the degenerative process This would indicate that abnormal stress must be regarded as an etiological factor

In the present experiment an attempt was made to induce degenerative changes in the knee joint in rabbits by altering the load bearing by means of valgus angular osteotomy of the tibia In view of the time factor a valgus angulation of 30 was chosen and 10 to 12 weeks was estimated to be the minimum observation time After that period no radiographical changes indicating osteoarthritis had occurred Only in one case were macroscopical changes observed whereas histological examination disclosed clearly initial degenerative changes of the cartilage and the underlying bone corresponding to the areas exposed to the biggest stress i e the lateral tibial and femoral condyles

The degenerative changes found resemble those described in connec



Figure 5 From the left lateral tibial condyle 10 weeks after osteotomy (case 13) Vessels indicated by black seem to penetrate from the subchondral marrow Thickening of the bone trabeculae in the subchondral one Haematoxylin eosin Magnification × 224

tion with human osteoarthritis (Sokoloff 1969) Among the initial degenerative histological changes the most constant finding was loss of metachromasia in the superficial layers of the cartilage This is probably due to a reduction in the content of chondroitin sulphate in the cartilage possibly on an enzymatic basis Based on this theory Bentley (1971) experimentally induced degenerative changes of the cartilage by means of intraarticular injection of the enzyme Papain which is able to liberate the chondroitin sulphate from the protein polysaccharide complex in the articular cartilage

Other initial degenerative changes (Sokoloff 1969) consisted in most

cases of changes of the surface in the form of fibrillation clefts or flaking Together with those changes loss of nucleic staining of the chondrocytes in the superficial layers was often found indicating necrobiosis (Salter 1960) and furthermore there was derangement of the cell column Proliferation of the chondrocytes in the form of clusters (Hulth et al 1970) is reported by Sokoloff (1969) as a regular finding especially at the bottom of the fissures on the surface This was also found in some of the sections The calcified zone and tidemarks were well preserved which is in accordance with the report by Thompson & Bassett (1970) on the basis of experimental compression tests Following compression early thickening of the subchondral bone trabeculae has also been seen (Salter 1960) corresponding to a moderate degree to the lateral condyles subjected to the biggest load

SUMMARY

On the basis of the clinical experience that loading of the knee by displacement for a certain period predisposes development of osteoarthritis in the area of the knee exposed to the biggest loading attempts were made to induce osteoarthritis experimentally on six rabbit knees by *means of valgus angular osteotomy of the tibia Valgus angulation* of 30 and an observation time of 10 to 12 weeks were employed The experiments demonstrated that no radiological signs of osteoarthritis occurred and that slight macroscopical changes of the lateral tibial condyle were found in only one case However clear initial changes were found histologically in the cartilage of the lateral tibial and femoral condyles in the form of loss of metachromasia fibrillation clefts and flaking in the superficial layers together with loss of nucleic staining Moderate sclerosis was found subchondrally

It is concluded that it would appear to be possible to induce initial degenerative changes analogous to human osteoarthritis by means of an experimentally induced alteration of the load bearing

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epiphysis and a partly iatrogenic pathogenesis is suggested. It is believed that slipping of the femoral capital epiphysis is due to a universal weakness of the growth zones, but the literature contains very few reports of epiphyseal damage located in other growth zones than the one in the hip.

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FEMORAL FRACTURES AFTER MOORE ARTHROPLASTY

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The Moore Arthroplasty has for some years been accepted as a reliable procedure in the treatment of fractures of the femoral neck in geriatric patients It is well known that fractures of the femur can result from rough manoeuvering during the operation but little attention has been given to late fractures around or below the intramedullary prosthesis In 1964 Parrish & Jones reported nine cases and Knud Jansen discussed the problems involved in dealing with these fractures in a paper read at a meeting of the Danish Surgical Association in 1965 The choice of treatment of these fractures seems to be wide open and is seldom discussed in reports of complications after arthroplasties The present study has concentrated mainly on the operative treatment of fractures secondary to an arthroplasty

MATERIAL

The basis of this report is twenty five patients all of whom have been treated in Department M Bispebjerg Hospital Copenhagen for a late femoral fracture (Table 1) The condition for which the arthroplasty was performed was a femoral neck fracture in all cases The operative procedure followed the instructions given by Austin Moore in 1957 Acrylic cement was not used

Table 1
Age distribution

70–79	13
80–89	11
90–	1
	25 (23 females 2 males)

As a rule the late femoral fracture had a spiral or an oblique form winding around the shaft of the femur or below the level of the prosthesis In five cases the fractures were placed around the stem of the prosthesis (Table 2) Fourteen fractures were localised at the level of or below the shaft of the prosthesis—all



Figure 1 Typical fracture around tip of prosthesis

oblique fractures with considerable instability (Figure 1) In the distal part of the femoral shaft three fractures were seen without direct relation to the Moore prosthesis In the condyle area three small undislocated fractures occurred These are only mentioned to complete the picture

Table 2

Site of fracture

Proximal	5
Around the tip	14
Distal	3
Supracondylar	1
Condylar	-
	25

Table 3

Time between arthroplasty and fracture (in years)

0–½	8
½–1	0
1–2	3
2–5	8
5–10	2
10–	3

(1 one case unknown)

In Table 3 the fractures have been divided according to the length of time between the arthroplasty and the occurrence of the fracture The fractures are classified into two groups A minority group of the patients sustained the fracture during the first months of the postoperative physical training The majority of the fractures occurred after at least one year when training was completed The longest interval has so far been twelve years

METHODS

The choice of treatment depended on the grade of dislocation (Table 4) Proximal fractures were all treated conservatively some with traction and some with a restricted bed regime Walking exercises started after four to six weeks In the first years a few dislocated fractures were treated with traction but later on internal fixation was preferred. Until 1967 circumferential wiring was used but since then plate fixation has been considered the most convenient method of dealing with unstable fractures

Table 4
Forms of treatment

Type	Conservative	Wire	Plate	
Proximal	5	0	0	
Around the tip	2	3	9	
Distal	1	0	2	
Supracondylar	1	0	0	
Condylar	2	0	0	
	11	3	11	25

Usually an eight hole plate of cobolt-chrome molybdenum alloy was adapted to the outline of the trochanteric and cortical area and fixed with eight screws (Figure 2) When the plate was situated on a level with the stem of the prosthesis a special drilling technique was used When the drill contacted the prosthesis it was retracted a few millimeters and set to a new angle tangentially to the stem which then could be passed without difficulties The patients were confined to bed for four to six weeks After discharge they were seen in the outpatients department

Few postoperative complications were encountered One patient died twenty eight days after the operation with a deep infection and a pulmonary embolus One patient died after twenty nine days in a psychiatric department The cause of death was unknown In all surviving patients the fractures healed without complications

DISCUSSION

Three conditions seem to be of decisive importance in the pathogenesis of femoral fractures after a Moore arthroplasty Alterations in the



Figure 2 Fracture in Figure 1 treated by plate an screws

*biomechanical factors in the femur severe osteoporosis and gait im*pairment

Insertion of an uncemented metallic prosthesis and the following biological integration of the prosthesis in the bone involves changes in the transmission of forces from the acetabulum to the femoral shaft As shown by Charnley (1964 1965) the forces will be concentrated in the calcar and the femoral cortex laterally to the lower pole of the prosthesis thus creating an area of high stress concentration The result can be a resorption of the remnant of the femoral neck and this will cause a loosening of the prosthesis and permit the tip to press on the endosteal part of the lateral cortex In some cases a significant augmentation of the thickness of lateral cortex will occur on the periosteal aspect In Figure 3 these tendencies are illustrated

Femoral neck fractures in elderly patients are considered by some authors to be an indirect result of senile osteoporosis (Nigst 1961) After insertion of a metallic prosthesis the osteoporosis will accelerate further and provoke a fracture at the point of highest stress concentration The trauma is always minimal In the presented material all patients except one sustained the fracture indoors from a small trauma In no case was a high energy impact involved

Figure 3 Loose prosthesis Note resorption of neck and lateral cortical hypertrophy



It is rather difficult to get an impression of the frequency of these fractures Only a few studies mention a percentage In many reports concerning the late result of femoral arthroplasties this complication is not referred to Riska (1971) found late femoral fractures in 3 3 per cent of patients followed up in contrast to another Scandinavian study (Andersson & Nielsen 1972) who did not find late femoral fractures at all In a paper read at a meeting of the Danish Surgical Association Knud Jansen and Ruben Hansen found two fractures in a total of thirty three patients (1965) The presented material does not allow any conclusion of the frequency because the patients were derived from different surgical departments in Copenhagen The precise number of arthroplasties in the decade 1963–1972 could not be found

In spite of the great operative risk in these geriatric patients there seems to be a tendency to consider internal fixation as the best solution in unstable femoral fractures (Parrish & Jones 1964 Huggler 1968 Muller & Boitzy 1968) Parrish suggested medullary nailing alongside the stem of the prosthesis supplemented with wiring Huggler and Muller both recommended stabilization with an AO plate Riska has used circumferential wiring as we did in our first operations Unfortunately this method does not provide a high order of stability and in addition requires a secondary operative procedure for removing the wires From a theoretical point of view the exchange of the prosthesis

for a long stemmed one may stabilise the fracture like an ordinary medullary nailing but this procedure has disadvantages because of difficulty in removing the prosthesis and it offers only a moderate stability to the fracture By comparison the lateral plating can be regarded as a minor procedure

In 1964 Charnley recommended cementing with acrylic cement to prevent loosening of the prosthesis This may be a realistic way to hinder some of the late femoral fractures by lowering the stress concentration in calcar and especially in the lateral cortical area Should a fracture occur in relation to a cemented prosthesis it can be treated with a lateral plate exactly as described In the drilling process the acrylic cement can be handled just like bone and gives sufficient hold to the screws

Fractures without dislocation should be treated conservatively with a restricted bed regime for four to six weeks Thereafter graduated walking exercises can be started This fracture type is located at the stem of the prosthesis and seems to have an inborn stability caused by the prosthetic hold on the femur

Unstable shaft fractures should be treated by operation as early as possible with an internal fixation by an eight hole plate The patient can be allowed to sit out of bed a few days after the operation Walking exercises may begin gradually three to four weeks later Antithrombotic prophylaxis should be initiated

SUMMARY

The insertion of an intramedullary prosthesis changes the biomechanical factors in the femur and induces stress concentrations, especially in the lateral cortex on a level with the lower pole of the prosthesis and may result in a late femoral fracture This complication does not seem to be frequent but gives rise to problems of treatment

Twenty five patients with a Moore prosthesis sustained a late femoral fracture Fourteen were operatively stabilised three with circumferential wiring and eleven with plates Eleven were treated conservatively Two of the patients died after four weeks In all other cases the fracture healed without complications The internal fixation with an eight hole plate is recommended as the most convenient method when the fracture is unstable Otherwise conservative measures are preferred.

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TREATMENT OF FRACTURES BY THE VIDAL-ADREY METHOD

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The method of immobilising fractures by transfixion of the bone fragments with nails or screws which in turn are fixed together by plaster-of-Paris or metal splints goes under the name transfixation. Lambotte introduced such a method as early as in 1902 and since then it has reappeared from time to time in different versions (Anderson 1934, Judet 1934, Hoffmann 1938, Stader, Jewis & Breidenbach 1942). The Hoffmann transfixation system has been used in Sweden by, among others, Orell (1956) and Felländer (1963), the latter in a study of fractures with delayed healing and pseudarthroses. The occurrence of infectious suppuration around the transfixation nails and in some cases lack of healing has resulted in a sceptical attitude towards this method. These adversities have been attributed to a lack of stability. Hoffmann (1951) and other authors (e.g. Ray 1964) have improved the stability considerably by duplicating the instrumentation. A similar effect can be obtained by steel pins passing through the fragments (Cuendet 1933), a method often used in arthrodesis of the knee (Key 1931, Charnley 1953, Muller 1955).

Vidal (1968) achieved considerable improvement of the stability with the Hoffmann apparatus by replacing the rods connecting the Hoffmann fixation clamps by a connecting frame (see Figure 1 d). This idea led to a biomechanical study (Vidal et al. 1970, Adrey 1970) in which the stabilizing capacity of the Hoffmann apparatus was investigated with different external connection arrangements. Four of the systems compared are sketched in Figure 1 and consist of:

(a) Fixation with 3–5 bone screws in each fragment. Each of these groups of screws is held in position by a fixation clamp. These clamps, in turn, are connected to each other by a simple connecting rod.

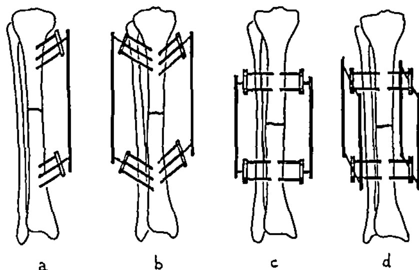


Figure 1 Schematic illustration of different methods of transfixation
a Three Hoffmann bone screws in each fragment connected by a single metal rod
b The same as (a) but in a duplicated version
c Steinmann pins passing through each fracture fragment connected on each side fixation clamps and single metal rods
d Steinmann pins passing through each fragment as in (c) but the fixation clamps are connected with other by two metal rods forming parts of a parallelogram

(b) Duplication of the system under (a) The respective systems are placed at an angle of 110 in relation to each other (This is a natural angulation for the tibia)

(c) Two or three Steinmann pins are placed in each fragment These pins are connected at each end by fixation clamps and connecting rods

(d) The same arrangement as under (c) The respective fixation clamps are connected here by two connecting rods which thus form part of the final frame holding the clamps in position

The stability i e the force needed to deform the fixation system increases considerably with the development of the connecting arrangement shown in Figure 1 a–d This is true for application of force both in the frontal and in the sagittal plane The most favourable system thus consists of Steinmann pins passing through the fragments and fixed in position by a connecting frame Application of the system to the tibia in a frontal plane has great advantages from the practical aspect

The most reliable stability is obviously when the fragments are in contact and press against one another Such an effect is achieved if the connecting rods are replaced by compression (telescopic) rods (see Figure 2 c), by which the fixations clamps and thereby the fragments can be forced to approach one another

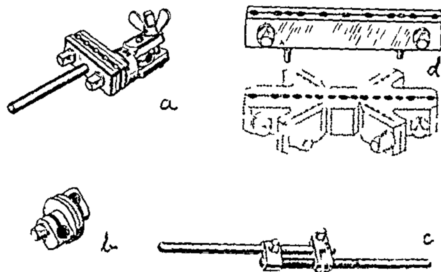


Figure 2

a Hoffmann s fixation clamp correctly supplied with a 5 cm long cross bar
b The retaining nut which connects the cross bar and the connecting rod
c Compression rod
d The special adapter that is mounted on the original Hoffmann adapter is illustrated in the upper part of (1)

In cases with cortical bone defects in which there is only partial contact between the fragments or none at all the frame system is quite superior to any other external fixation device

Following the introduction of the Vidal Adrey arrangement for transfixation of fractures Hoffmann s original instrument system has been modified and complemented Thus the fixation clamp has been supplied with a 5 cm long rod (Figure 2 a) This fixation clamp is attached to the connecting rods (in the compression version illustrated in Figure 2 c) via a retaining nut (Figure 2 b) which by a simple manoeuvre locks the connecting rod and the rod of the fixation clamp into the desired position

Positioning of the Steinmann pins is facilitated by the use of a

special instrument (Figure 2 d) which is placed on the adapter originally intended for bone screws This instrument gives good guidance for the steel pins

Transfixation by the Vidal Adrey method may be regarded as a complement to other methods of treatment of fractures and according to its advocates its indications are well defined (a) open fractures with severe extensive soft tissue injuries and (b) infected fractures particularly infected pseudarthroses

In the open fracture the immediate measures can thus be limited to excision of devitalised tissue No further exposure of bone is required and attention can then be paid to retaining the vascularity of the fracture ends The wound may be left open with advantage which is of particular value from the point of view of prophylaxis against infection (vessels and nerves and also preferably tendons should however be covered with skin primarily if possible) Mounting of the instrument is simple but the positioning of the fracture fragments is somewhat laborious and time consuming Three Steinmann pins 4 mm in diameter are required in each fracture fragment When Steinmann pins are used in cortical bone they have to be inserted with a hand drill in order to avoid thermal damage to the bone Obviously it is best if the pins pass through the centre of the bone The best stability is obtained if the fracture surfaces are compressed against one another In cases where this is possible telescopic rods should be used The compression applied should be sufficient to cause very slight bending of the Steinmann pins

In practice it is found however that the compression is partly lost during the first week so that it sometimes has to be reviewed With clean oblique fractures it is of value to produce a surface perpendicular to the longitudinal axil of the bone by which the fracture ends can be hooked up Compression can then be applied which is otherwise not possible in these cases If there is an intermediate fragment this can be attached to the main fragments by an internal compression screw but otherwise external fixation can be used

In the case of the femur the instrument is most easily mounted with the patient placed on an extension table In the distal third of the femur the same technique can be used as for the tibia In fractures higher up a special technique is used in order to avoid damage to the large vessels The bone screws are inserted both from the lateral side and from the ventral side of the femur so that the two groups of screws will lie at an angle of 90 to each other In the distal part of the

femur Steinmann pins are used throughout The two lateral fixation clamps are connected to each other by the frame described above The medial fixation clamp is connected to the fixation clamp mounted on the ventral group of bone screws The tendency to rotation in the system is prevented by mounting the fronto-medial connecting rod against the lateral frame The mounting system is shown in Figure 9 Compression using telescopic rods increases the stability considerably and should be used whenever possible

Transfixation of the femur with the bone screws placed at an angle to one another would hardly seem suitable in cases where it is an aim to retain an intact knee function because the bone screws inserted ventrally in the femoral shaft will interfere with the function of the quadriceps The method should therefore be limited to those cases where because of other circumstances retention of an undisturbed knee function is not possible

The alignment of the fracture need not be absolutely correct from the beginning as there is a possibility of changing the position later as long as the fracture has not consolidated The patient can then be placed on an extension table the clamps released and the position of the fracture adjusted In comminuted fractures and cases with bone defects adjustment can be made for shortening With an X ray image intensifier and television monitor the correct length is measured on the intact side and the fracture side is then corrected The fixation clamps are then adjusted definitively

With the transfixation method there is of course a risk of infection where the Steinmann pins pass through the skin Experience has shown however that when such infection occurs it is seldom serious Secondary infection consisting of secretion and granulation tissue around the pins or screws indicates instability This heals as long as stability exists and drainage of the pin wounds through the skin can be ensured Reapplication of the transfixation may be required in the event of such a complication

In order to reduce the possibility of bending of bone screws or Steinmann pins the fixation clamps should be mounted as close to the skin as possible A shorter distance than about 2 cm however makes it difficult to renew dressings and clean the skin close to the metal pins which is necessary at intervals

In the early posttraumatic stage the limb may be suspended in a balanced elevated position to reduce swelling The cords used for this purpose may suitably be attached to the transfixation material Care



Figure 3 Balanced suspension of the extremity facilitates joint exercises and stimulates the muscles and circulation

of the skin and wound are facilitated in this way Conventional dressings are not necessary (Figure 3)

The fixation allows free movements of all joints of the extremity from the beginning (with the exception of femoral fixation) As soon as the acute swelling has subsided the patient is allowed to get up Compression of the soft tissues is then often advisable to reduce swelling Some weight bearing on the extremity certainly up to about 10–20 kg may be permitted Most patients have no difficulty in managing the instrument themselves at home

The fracture healing is checked both by roentgenological examination and by loosening the connecting rods and testing the stability If the fracture seems to be clinically consolidated the instrument system is removed At this stage the fracture healing may not be completely reliable and it may therefore be suitable to apply a PTB walking plaster to the lower extremity for 4–6 weeks

At the University Hospital in Uppsala the duplicated version of the

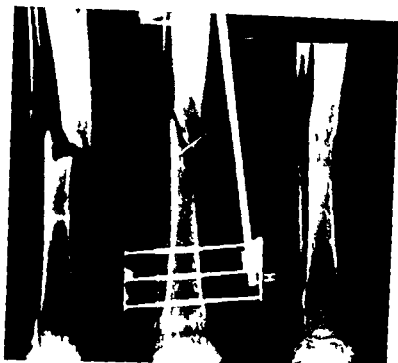


Figure 4. Roentgenograms of the fracture described in Case 1 (see text).

Hoffmann instrument has been used previously on a few occasions and with special indications. But since the work of the Montpellier group (Vidal, Bonnel, Adrey, Rabischong) has become known, we have followed the transfixation principles of these authors more systematically. The following case reports illustrate the indications for which we have used the method described.

Case 1. A 60 year old male cyclist was run over by a car. He sustained a tibial fracture (Figure 4) with skin necrosis almost the size of the palm of a hand over the anterior and medial aspect of the tibia. After primary traction for 7 days the fracture was treated with transfixation. At the same time, in collaboration with a plastic surgeon, a skin flap was taken from the back of the calf which was then covered with a split skin graft. Satisfactory healing of the skin and soft tissues ensued. The fracture showed early callus development with complete consolidation after 3 months. The patient was completely restored 4 months after the accident.

Case 2. A 17 year old boy had a motorcycle accident and sustained an open supracondylar intraarticular fracture and also an open tibial fracture with extensive soft tissue injuries (Figure 5 a); the tibial fracture included complete loss of about 10 cm of the tibial shaft (Figure 6). The tibial fracture was transfixed by the Vidal Adrey method (Figure 5 b) and at the same time the wound was thoroughly



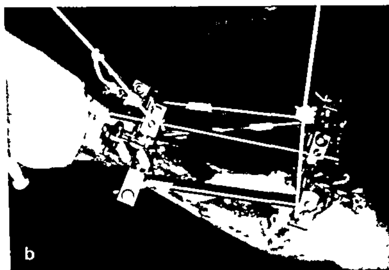


Figure 5
a The injured leg in Case 2 (see text)
b Three weeks after the double frame fixation there were clean granulation surfaces ready for split skin grafting

cleaned The skin was only partially sutured and large parts of the wound were initially left open In the same session the femoral fracture was treated with a stable angle plate osteosynthesis

The leg was treated in balanced suspension (Figure 3) Split skin grafting was



Figure 6 Series of roentgenograms of the fractures in Case 2 (see text)



Figure 7 Roentgenograms of Case 3 (see text)

applied to the open areas on the lower leg except for the area where the bone of the tibia was exposed (Figure 5 b) Cancellous bone grafting was performed on the lateral side of the tibial fragments and along the bone defect 2½ months after the accident Six weeks later a further bone graft was applied to the interosseous membrane from the posterior side to connect tibia to fibula above and below the defect The patient was hospitalized initially for 4½ months and subsequently for short periods for the necessary surgical measures Knee and ankle exercises were encouraged throughout the healing phase Partial weight bearing was allowed after about 6 months Shortening of the tibia by 2½ cm had to be accepted Seven months after the accident the fracture was consolidated (Figure 6 d) A PTB plaster was used for a further 3 months and 12 months after the accident the patient was able to walk without either plaster or crutches After 16 months the patient only had a slight limp which was corrected by a 2 cm compensation

Case 3 A 17 year old girl sustained a comminuted crush fracture of the left femoral shaft There was considerable skin damage covering practically the whole of the dorsal aspect of the thigh Roentgenograms showed a large cortical bone defect (Figure 7 b) Traction was applied primarily for 4 weeks until the thoracic and abdominal injuries had healed after which Vidal Adrey transfixation of the femoral fracture was undertaken (Figure 7 b) After a further 14 days the patient was placed on an extension table for correction of angles and bone length with the aid of an X ray image intensifier with television monitor After two bone graft procedures bridging callus filled the bone defect (Figure 7 c) Ten months after the accident the patient was able to walk without crutches and after another 4 months no actual limp existed. The knee function is somewhat reduced however with a flexion range from 0 to 100

Case 4 This patient a 34 year-old woman had a fracture of the femoral shaft which was treated primarily with a Kuntscher nail The fracture was severely infected from the very beginning After one year the nail was removed without the fracture having healed and a plaster-of Paris was applied for the following 8 months after which sequestrectomy was performed (Figure 8 a) Two and a half years after the accident further sequestrectomy was performed + a bone graft + transfixation (Figure 8 b) Even after this operation there was exacerbation of the infection necessitating further drainage measures Although there was satisfactory stability which after 6 months was increased by compression by replacing the connecting rods by telescopic rods (Figure 9) the callus formation was rather poor and a further bone graft was therefore performed After 12 months the instruments could be removed. Three months later full weight bearing was allowed

Case 5 A 70 year old man was involved in a traffic accident and sustained multiple injuries In addition to a grotesque supracondylar intraarticular open femoral fracture (Figure 10) there was considerable soft tissue damage below the knee on the same extremity He also had a radio ulnar fracture combined with a practically total injury to the brachial plexus After tuberosity tibial traction for a month restoration of the femoral condyle plane with a minimum of osteosynthesis material was undertaken Stabilisation by Vidal Adrey transfixation technique was performed and after a further 6 weeks a cancellous bone graft Three

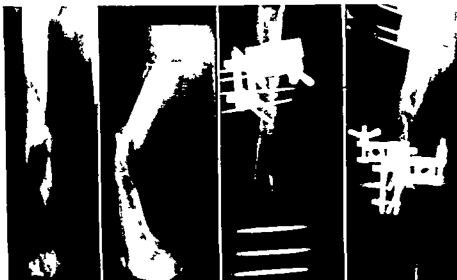


Figure 8 Roentgenograms of Case 4 (see text) Fixation of the femoral fracture consisted of four ventrally and four laterally inserted screws in the proximal part of the femur Steinmann pins were passed through the femoral condyle area

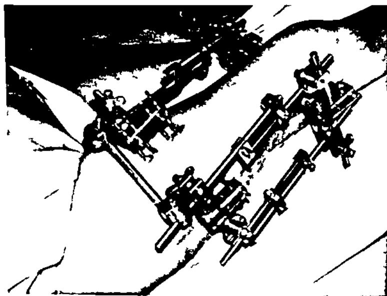


Figure 9 In order to increase the stability compression of the pseudarthrosis was performed in this case with telescopic side rods

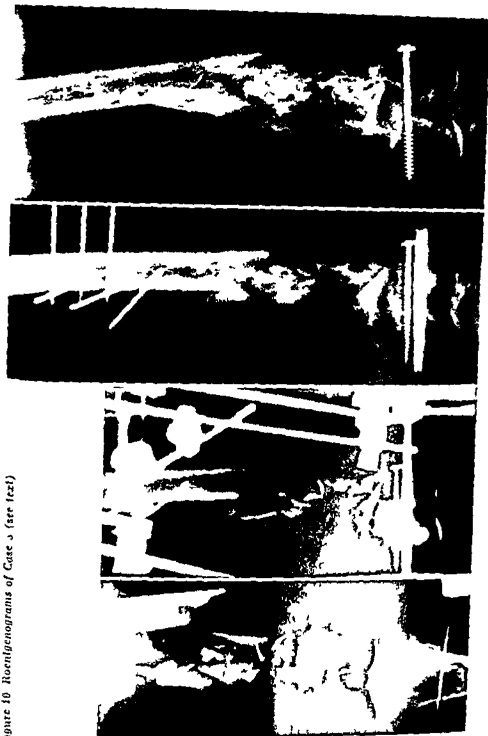


Figure 10 Roentgenograms of Case 5 (see text)

months after the accident mobilization of the patient was gradually started with walking exercises in a walking chair and partial weight bearing Twelve months after the accident the transfixation material was removed Fourteen days afterwards there were signs of refracture Further transfixation in the same manner as earlier and another bone graft were performed After a further 4 months the fracture was clinically and roentgenologically consolidated and the transfixation material was removed (Figure 10 c and d)

COMMENTS

In the cases described above treatment with transfixation was performed on definite indications and offered decided advantages In Case 1 satisfactory fixation was obtained at an early stage which rendered possible early skin grafting to compensate the extensive skin damage Internal fixation was avoided as in the prevailing situation it might have involved certain risks Considering the circumstances there was surprisingly early consolidation of the fracture and good vascularization in the fracture ends certainly contributed in this respect

In Cases 2 and 5 the injuries were so extensive that amputation was seriously considered as an alternative measure at the time of admission However the transfixation procedure gave adequate fixation and stability The fairly large bone defects were refilled with cancellous bone grafts with the transfixation instrument still in place In Case 2 remarkably rapid consolidation took place while in Case 5 this was very slow certainly in part due to the relatively advanced age of the patient

The transfixation in Case 3 meant a considerable advantage in permitting a skin graft on the back of the injured thigh and made it possible to retain the length of the extremity as well as the correct conditions with respect to the frontal and sagittal plane and the correct degree of rotation The knee function naturally suffered from this fixation procedure and the total flexion capacity 14 months after the accident ranged from 0 to 85 but then improved spontaneously to 100

In Case 4 the transfixation procedure greatly facilitated the flushing and draining necessitated by the infection Further the reliability of the method rendered relatively early ambulation possible and the patient was able to walk fairly easily with the aid of crutches She was thus able to spend long periods at home which must be considered a decided advantage from the aspect of both the patient and the hospital services

Transfixation by the Vidal Adrey technique does not only provide an alternative form of treatment of certain fractures Under especially severe circumstances this method seems to be the only reasonable approach if the risk of complications is to be kept at a minimum and yet a fully acceptable final result obtained

SUMMARY

Treatment of fractures with transfixation procedures has taken place throughout the 20th century Both the methods and the instruments used have had certain disadvantages, especially in the form of deficient stability However with the Hoffmann instrument connected to Steinmann pins passing through the bone and over a frame on each side of the fracture the stability has been increased considerably Secretion and suppuration around the metal pins as disadvantages of the transfixation system no longer constitute any problem This technique is especially suitable in open fractures and in infected cases particularly infected pseudarthroses The method in itself gives complete stability and therefore no further fixation is necessary Because of this stability joint movements and mobilization can be started at a very early stage after injury which is of great value especially in fractures with extensive soft tissue injuries In such fractures in particular this new transfixation technique appears to be a very valuable form of treatment

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MYOPLASTY FOR COVERING EXPOSED BONE OR JOINT ON THE LOWER LEG

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During recent years several reports have appeared on series treated successfully by myoplastic operations for covering skin defects on the lower limbs (Ger 1968 1970 a b Bonc Andersen & Helmig 1970 Barfod & Pers 1970, Ger & Efron 1972) After the Department of Orthopaedic Surgery was established in the Gentofte Hospital in October 1970 this operative method was included among the possibilities available for covering denuded bone on the lower leg In eight cases we found this treatment indicated

METHOD

The principle of the procedure is to cover the exposed bone with a vital muscle belly and thereafter skin cover is obtained by a split skin graft primary or primary delayed The choice of muscle belly depends upon the site and size of the skin defect as well as the localization of associated soft tissue injuries

Applicable muscle bellies are the medial belly of the gastrocnemius soleus flexor digitorum longus and the peronei By means of these muscles it is possible to cover defects from the knee joint almost down to the malleoli The medial malleolus may be covered with the abductor hallucis (Ger 1968) and the lateral malleolus with the extensor digitorum brevis (Reumert 1973) Ger (1971) has described the technique except that concerning the last mentioned muscle

CASE REPORTS

Case 1 A 57 year old man was admitted with a left sided complicated fracture of the left lower leg which was treated primarily by wound excision plate osteosynthesis and skin suture Three months later the plate had to be removed because of wound infection Muscle flow examined with Xenon[133] showed values at the lower

end of the normal range. At operation 6 months after the accident a 2 × 2 cm skin defect was covered with the belly of the *flexor digitorum longus* The muscle was then covered with a plit skin graft About one third of the graft healed primarily and the remainder became covered by epithelialization from the edges Eleven months after the myoplasty the fracture had finally healed Two years after myoplasty there were no complaints due to the lack of the flexor digitorum longus the patient being able to flex the distal joints of the toes presumably by means of the quadratus plantae The fracture site showed a solid skin cover

Case 2 A 37 year old woman was admitted with a tumour just distal to the right medial tibial condyle. It had been growing slowly for 2 years Neither a biopsy nor the tumour removed *en bloc* showed any signs of malignancy Two months later she had a recurrence Lymphography did not reveal any signs of metastases Arteriography indicated malignancy but a repeated biopsy still showed no signs of malignancy *En bloc* dissection left a skin defect measuring 20 × 20 cm and at its bottom 8 cm of the anteromedial part of the tibia was denuded In addition the medial collateral ligament had to be removed, but without opening the knee joint. The exposed bone could just be covered by the belly of the *medial gastrocnemius* The entire skin defect was covered primarily by a split skin graft. The final histological diagnosis was myxosarcoma Valgus instability was demonstrable but the knee was stable in walking Nine months later metastases appeared on the medial aspect of the right thigh and in the right pelvis and in another 10 months death ensued

Case 3 A 22 year old woman was admitted in 1966 with a complicated fracture high on the left lo er leg It was primarily treated by wound excision reduction and immobilization in plaster After several operations for non union and procedures done because of complicating infection a Nicoll operation for non union was performed 5 years later This operation was complicated by skin necroses over the bone graft Three weeks later it was attempted to cover the denuded bone with the medial belly of the *gastrocnemius* which was passed beneath an intact bridge of skin Purulent discharge soon appeared and the bone was again denuded Five months after the operation for non union a cross leg flap was applied. It was primarily successful but again a fistula arose and at the same time there was a 2 5–3 cm bone defect in the already shortened tibia As the final union of the fracture was doubtful and would in any case be prolonged it was decided to perform a below knee amputation This was done without complications Incidentally the remains of the transposed muscle belly contributed to affording a solid soft tissue cover of the stump

Case 4 A 21 year old man was admitted with a complicated fracture of the left lower leg and disruption of all anterior and lateral leg muscles (Figure 1) The fracture was immobilized in a Hoffmann apparatus and covered with the proximal part of the torn muscles A large skin defect was covered with a split skin graft Some of the transposed muscles underwent necrosis (Figure 2) Eight weeks after the accident the necrotic tissue was removed and a 6 × 7 cm defect over the fracture site was covered with the medial belly of the *gastrocnemius* The muscle was primarily covered with a split skin graft (Figure 3) One year after the accident the

of the lateral malleolus The denuded bone was covered by reversing the belly of the *extensor digitorum brevis* over the defect Solid closure was obtained laterally but in 6 weeks a perforation appeared on the medial side of the ankle The arthrodesis was still unstable Now 4 months after the myoplasty the patient has been admitted to another hospital from which it is reported that revision and rearthrodesis have been performed without compromising the skin on the lateral aspect of the ankle

Case 7 A 59 year old woman was admitted with an open trimalleolar fracture sustained 12 hours previously Primary wound excision suture and reduction was performed A fistula appeared in the wound leaving a skin defect of 1 × 3 cm over the medial malleolus communicating with the joint

Three and a half months after the accident the joint was closed by means of the *abductor hallucis* which was exposed by an incision into the medial aspect of the foot To avoid constricting the vessels of the muscle this incision was connected to the primary defect The skin defect was primarily covered with a split skin graft The soft tissue cover of the malleolus is now two months later sufficiently stable for performing arthrodesis which will presumably be needed

Case 8 A 69 year old woman was admitted with a right sided bimalleolar fracture as well as an open low spiral fracture of the left lower leg After wound excision of the large, curved wound on the left lower leg the fracture was immobilized by 3 crossed screws There remained a 15 × 10 cm skin defect in which the tibia was exposed in an area almost 10 cm in length This defect was covered by the belly of the *soleus muscle* Because of oozing bleeding from the fracture site the wound was covered with towels moistened in saline and 48 hours later the soleus muscle was covered with a split skin graft which took 100 per cent At the most recent follow up 3 months after the accident the soft tissue cover was perfect but the fracture line was still distinct and there was no definite formation of callus

DISCUSSION

Among the eight cases a cross leg flap was unsuitable in Case 2 because of the size of the defect and in Cases 1 5 6 7 and 8 because of the patients age and relatively reduced vascularization In Case 4 the defect was not too large to be covered with a cross leg flap but it was felt expedient to employ the medial belly of the gastrocnemius since all the antagonists were already non functioning None of the other patients had complaints that could be ascribed to lack of muscle function

In two cases (Nos 2 and 5) the myoplasty proved a marked advantage above other methods as it simultaneously afforded skin cover and active stabilization of the knee joint and ankle joint respectively

It has been pointed out that preserved innervation of the muscle is necessary for a successful result This applies most particularly to

cases in which the transposed muscle is to take over the function of a ligament In two instances (Cases 1 and 7) there was by clinical criteria no preserved function of the muscle but the goal to produce a skin cover over the bone was nevertheless attained

In Case 7 where the abductor hallucis was used coverage of the open ankle joint required a very extensive exposure right back to the origin from the calcaneus Nevertheless the muscle did not reach further than just to cover the defect over the ankle joint Proximally the defect reached a little further and could be covered by suturing the skin edges but if the defect had been just a little bit larger the belly of the flexor digitorum longus would have been required for cover

In the two cases in which the myoplasty was unsuccessful the explanation was presumably as follows In Case 3 the muscle belly was placed in a tunnel limited by bone and a skin bridge and thereby it was strangulated Ger (1971) has warned against this complication In the other case (Case 6) the infection was not sufficiently subdued perhaps because the resection did not include sufficient bony tissue We have not had any late complications Ger (1970 b) suggested pressure by shoes as the cause of late muscle necrosis following transposition of the abductor hallucis

The problem whether grafting should be primary primary delayed (1 2 days) or deferred for 5–7 days as advocated by Ger (1971) cannot be decided on the basis of the present series We feel that it should always be primary In Case 8 however haemostasis was not satisfactory and the skin defect was not covered until 2 days later with split skin which nevertheless showed a 100 per cent take

CONCLUSION AND SUMMARY

Like previous authors we can conclude on the basis of eight operated cases that myoplasty for covering denuded bone on the lower leg as well as an open knee joint or ankle joint is an important alternative to transposition flaps and cross leg flaps Myoplasty is even superior to these methods in elderly patients patients with open joint injuries and patients with particularly extensive soft tissue injuries

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SURGICAL TREATMENT OF METASTATIC PATHOLOGICAL FRACTURE OF MAJOR LONG BONES

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Accepted 1 iv 73

Pathological fracture of major long bone induced by malignant tumour metastasis is comparatively rare in series of surgical patients but surgeons are now and then called upon to consider the possibilities existing for treatment of such cases which have not received much attention Reports have been presented by Beals et al (1971) Bennish & Hammond (1955) Bremner & Jelliffe (1958) Devas et al (1956) and MacAusland & Wyman (1970) in which the advantages achievable by osteosynthesis and by endoprostheses have been stressed According to Devas et al (1956) and Donaldson & Horsley (1970) the most common primary tumours inducing metastatic fractures are cancer of the mammary glands and of the lungs but metastases are also sent out into the bones by other malignant tumours where they may produce pathological fractures

Fracture of a long bone due to metastasis may heal by the aid of callus formation produced periosteally particularly if the lesion is given proper treatment but the healing tendency of such a pathological fracture is inferior to that of a fracture occurring in an intact bone One should therefore take into account in planning the treatment that conservative treatment may confine the patient to bed for an unreasonably long period of his remaining life span It is for this reason that surgical treatment is now being resorted to in order to stabilize the bone and rehabilitate the patient although the prognosis is poor and the survival period may be short The aim of such surgical treatment is above all to mobilize the patient by restoring his mobility thus releasing him from bed and reducing pain during nursing Walking with aids is possible regardless of whether bony union is achieved stable osteosynthesis being the means for producing such a result In

Table 1 Age distribution (11 men 34 women total 50 fractures)

Age (years)	Patients
30–39	2
40–49	7
50–59	9
60–69	20
70–79	4
80–89	3
Total	45

some cases even fracture consolidation and restored functional ability of the extremity can be achieved

MATERIAL

The material from 1960–1970 of 50 metastatic fractures in 45 patients was subjected to retrospective analysis in order to clarify the results of surgical treatment and the indications for surgery

The age distribution of the patients can be seen in Table 1 The majority were elderly patients a fact which was significant as regards fitness for operation and postoperative ability to move Sixty six per cent of the patients were over 60 years of age *The sex distribution* (Table 1) shows that three-fourths of the patients were women

Table 2 Establishment of primary tumor and metastatization

Type of primary tumour	Total	Time of discovery: prior to fracture		Time of discovery: in connection with fracture	Metastasis: solitary	Metastasis: multiple
Cancer of breast	21	21			3	18
Cancer of lung	7	5		2	2	5
Hypernephroma	3	2		1	1	2
Cancer of bladder	2	2			1	1
Cancer of uterus	1	1				1
Myeloma/Leucaemia	5	2/0		2/1	3	2
Sarcoma	1	1				1
Undiscovered	5		(5)		2	3
Total	45	34	(5)	6	12	33

Table 3 Site and surgical treatment of 50 pathological fractures

Site		Method of treatment: Medullary nailing	Nail plate	Endo prosthesis	L-plate	Plaster cast
Femur	collum		3	4		
„	trochanteric		8			
	subtrochant	1	9			
„	diaphysis	17				1
„	supracondylar				1	1
Humerus	collum					1
„	diaphysis	3				1
Total		21	20	4	1	4

The type of primary tumour the time of its discovery with reference to the fracture and *the extent of metastatization* are presented in Table 2 The primary tumour of 34 patients had been established and treated prior to the fracture caused by its metastasis in 11 the pathological fracture was the first symptom of malignant disease necessitating a search for the tumour in addition to treatment of the fracture The search was unsuccesful in five cases the terminal phase ensuing before the location of the tumour could be found In most of the present cases treatment of metastases had also been necessary prior to the pathological fracture and to this purpose radiotherapy cytostatics hormonal treatment or hypophysectomy and adrenalectomy had been applied The metastasis responsible for the fracture had been irradiated in only two cases

The location of the fracture can be seen in Table 3 The largest group consists of fractures metastatic to mammary carcinoma of the diaphysis of the femur or of its trochanteric *region*

Methods of treatment

Table 3 also shows the surgical procedures applied in the present series Most common were medullary nailing according to Kuntscher and nail plate osteosynthesis It is a fact deserving notice that the material does not include any fractures of the lower leg

Fourteen patients received postoperative radiation treatment of the metastasis which had caused the fracture by X ray or telecobolt device the metastatic lesion of two others had already been subjected to radiotherapy prior to the fracture In 11 patients no postoperative treatment of the fracture inducing metastasis was possible by any method owing to poor general condition in the cases fitted with an endoprosthesis the region was not postoperatively treated after resection of the affected bone tissue In 12 cases hormone treatment or cytostatics were used hypophysectomy was performed in 2 cases and adrenalectomy in one. Apart from the endoprosthesis operations, no resection of destroyed bone was attempted in connection with the stabilizing procedure

Table 4 Postoperative mobility of patients with fracture of lower extremity

	Number of fractures
Walking unaided or with crutches	20
On crutches with assistance	5
Able to sit	13
Bedridden	5
Total	43

RESULTS

Bony union Distinct bony union of the fracture observable in X rays ensued in 7 cases (see Figure 3) In the rest the osteolytic process continued or the survival period was too short for consolidation to occur Of the cases in which bony consolidation ensued mammary carcinoma was present in 5 hypernephroma in one and carcinoma of the lung in another The location of the fracture was in the diaphyseal region of the femur in 5 cases in its trochanteric region in one and in the diaphysis of the humerus in another The metastasis of pulmonary carcinoma had received full X ray treatment just before the fracture occurred whereas radiotherapy was given to the other 6 patients after the wound had healed

Ability to move after operation 58 per cent of the patients regained at least a temporary ability to walk though mostly only with the aid of a stick or crutches Table 4 gives the details of the patients mobility after surgery

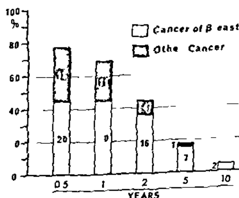


Figure 1 Survival periods after establishment of the primary tumour

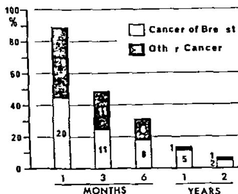


Figure 2 Survival periods after surgical treatment of metastatic fracture

Survival period One patient with myeloma died eight days after the operation from an intestinal haemorrhage The survival periods of the other patients both those counted from the operation and those after establishment of the primary tumour can be seen in Figures 1 and 2 Three months after the operation 48 per cent of the cases were alive whereas the survival percentage after six months was 30 but after one year no more than 14 The longest survival period was 2 years and 8 months

The cases with mammary carcinoma are shown separately in the figures it can be seen that their proportion from the survivor groups increases with increasing survival periods and is at 2 years and at 10 years after establishment of the primary tumour 80 and 100 per cent of the respective group It is further possible to conclude from both figures that in most of the present cases the pathological fractures did not occur until the malignant disease had already been present for a fairly long time and was approaching its terminal stage

CASE REPORTS

The following cases illustrate the methods of treatment applied and the results achieved

Case 1 A woman aged 49 subtrochanteric fracture of the femur caused by the only metastasis observed 2 years after radical mammary surgery and postoperative radiotherapy The treatment was fixation with a Jewett fixed angle nail plate and postoperative radiotherapy The patient was immediately able to walk with crutches and 4 months

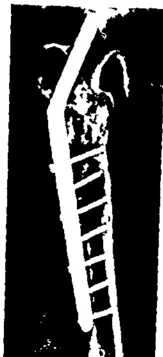


Figure 3 Destruction cavity of a metastasis of mammary carcinoma and a subtrochanteric pathological fracture running through the proximal part of the cavity Postoperative X ray 4 months after Jewett osteosynthesis and after postoperative radiotherapy revealed bony consolidation

after the fracture had consolidated (Figure 3) without crutches Survival period 8 months

Case 2 A woman aged 67 trochanteric fracture of the femur caused by the only metastasis observed 3 years after radical mammary surgery The treatment was fixation with McLaughlin s nail plate bony union ensued after postoperative radiotherapy The patient was able to walk and was still alive more than two years later when there was already multiple metastatization (Figure 4)

Case 3 A woman aged 65 radical mammary surgery oophorectomy and adrenalectomy There was multiple metastatization when fracture of the diaphysis of the femur occurred 4 years after surgery on the primary tumour Fixation by intramedullary nailing (Figure 5) merely facilitated the general treatment in bed of the patient s poor condition during the remaining 3 months This case reveals the possibility of using nailing for reinforcement of other metastatic regions in the same bone

DISCUSSION

Fracture may occur in a bone weakened by metastasis either suddenly whereby the extremity loses its stability or gradually by micro-frac



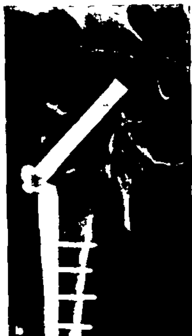




Figure 4 Subtrochanteric fracture of the femur from metastasis of mammary carcinoma, preoperative X ray (a) Osteosynthesis with a McLaughlin nail plate (b) Bony consolidation appeared after postoperative radiotherapy although owing to collapse of the destruction area the nail was driven in cranial direction in the collum The continuation of destruction more distally points to the prophylatic significance of a long side plate (c 16 months after operation) Powerful calcinosis of femoral artery appeared after the fracture



Figure 3 Fracture of diaphysis the femur in the large bone destruction area of a metastasis from mammary carcinoma (a) Intramedullary nailing provided good fixation and furnished good prophylactic protection of the incipient destruction areas seen more distally (b)

tures and infraction in which stress pain in the damaged region is a prodromal symptom The dislocation is usually slight in the beginning but it increases under load and for instance in fractures of the proximal part of the femur a typical varus deformity rapidly develops

A metastasis induced fracture may undergo bony consolidation if enough is left of the patient s life span In the present series more than half of the patients died before three months had passed after the operation therefore there was no chance of achieving consolidation of the fracture The bony union of a metastatic fracture appears to be essentially affected by the type of the tumour and by its response to palliative treatment If the destructive process cannot be checked an increasing defect develops between the ends of the fragments which the callus formation is unable to overcome In this respect medullary nailing has proved to be an advantageous fixation method it permits at light stressing of the extremity the ends of the fragments to meet or at least to approach each other if the end of the nail protrudes proximally Such compression may sometimes also occur in nail plate fixing (Figure 4) With regard to the chances of bony union cases of mammary carcinoma were found to be the most favourable in this

series Postoperative radiotherapy does not preclude the callus formation although from the present material nothing can be learned about the possible degree to which it delays the process

In this study the site of the fracture was the femur in 90 per cent of cases which is consistent with the frequencies in the surgical series presented by Bremner & Jelliffe (1958) The cases of femur fracture profit most from surgical treatment whereas fractures of the tibia and humerus are well suited to conservative treatment and rarely appear in any surgical series

The most suitable method of operation in the region of the diaphysis is medullary nailing which was exclusively used in the present series This method has recently been recommended for prophylactic treatment of femur metastases by Beals et al (1971) It is especially suitable in cases with multiple metastatization in the fractured bone In fractures of the trochanteric region nail plate fixing is appropriate The fixed angle nail allows weight bearing even if no bony union has taken place As a prophylactic measure the use of a long side plate should be borne in mind if other metastases are simultaneously observed in the shaft of the femur Endoprostheses are highly appropriate in metastatic fractures of the region of the neck of the femur

In spite of the advanced age of the patients there was no operative mortality in the series Substantial improvement of the patient s mobility was achieved in 58 per cent of cases although bony consolidation ensued in only seven cases of the series

The treatment of metastatic pathological fractures is merely palliative and such patients mostly have a short life span after surgery But since the prognosis is frequently difficult to assess in individual cases particularly in those of mammary carcinoma there are indications for giving most of these patients the benefit of surgical treatment without indulging in excessive pessimism It must be considered a *prerequisite* for surgical treatment that the patient s operability ensures a reasonable chance of survival The fractured fragments should contain enough healthy bone to render a stable osteosynthesis possible In addition to the group of fractures of the femur which is most notable in practice medullary nailing may be applied in diaphyseal fractures of the humerus with an extensive area of bone destruction whereby the upper extremity can be made functional

Fractures close to the knee joint may also be immobilized by plaster cast although the use of an L plate may be indicated It is thought that tibial fractures may well be immobilized by plaster and the patient s

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RECONSTRUCTION OF THE KNEE BY PEDICLED PATELLAR TRANSPLANT

R Merle d'Aubigné

Accepted 10 ii 73

When a femoral condyle or a tibial tuberosity is destroyed by trauma or infection or has to be removed for tumour knee arthrodesis with or without graft is the most currently accepted procedure

But ankylosis of the knee is a severe infirmity and when a sound femoro tibial joint is preserved on the medial or lateral side, preservation of the knee function by reconstruction of the condyle appears as highly desirable This should be possible theoretically in three ways inert prosthesis homogenous bone graft or as we propose, pedicled autograft

Inert prosthetic replacement of one condyle should be possible but would need a big material especially after large resection of a tumour superficially placed as it would be the risk of the suture breaking up with primary or secondary infection is to be feared

Replacement of the condyle by a massive homogenous free graft with its cartilage is possible provided a suitable material is obtainable a very hazardous condition except probably in Moscow But it has been shown clinically (Lexer 1909 Burkle de la Camp 1959) and experimentally (Herndon & Chase 1952) that such a graft would undergo massive necrosis it would unite with the host bone and probably provide a good function for some time but disorganisation collapse of the bone and absorption of the cartilage would certainly occur during the slow process of revascularisation and reconstruction by creeping substitution

By deep refrigeration as a means to reduce antigenic power of the graft Volkov (1970) has published better results but follow up of his cases is still a little short

At the present time a vascularised transplant appears more likely to stand the stress and strain of an articular surface

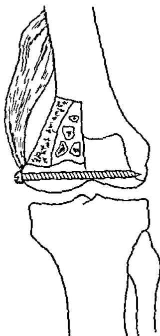


Figure 1 Diagram of the operation Reconstruction by pedicled patella of a femoral condyle after resection

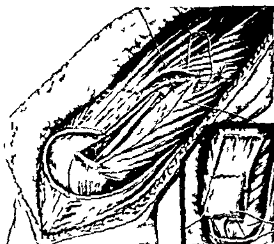


Figure 2 The patella is fixed to the remaining condyle by a screw its anterior surface covered by the fascia replaces the articular surface A cortical graft (auto r homogenous) is placed between the femur and the patella. Reconstitution of the quadriceps tendon using the tendon of rectus femoris



Figure 3 Case 2 Male 19 years A Destruction of femoral condyle by war wound B–C 19 years after resection and reconstruction by pedicled patella and cancellous grafts

MATERIAL AND METHODS

In 1945 we used patella transplanted with a vascular pedicle to reconstruct a destroyed femoral condyle in two cases of war wounds both enjoy a mobile and stable knee 25 years later (Figure 3)



Figure 3 D-E Left knee stable and mobile

Nine other cases have been submitted to the same operation one was traumatic one was a child with condylar destruction due to osteomyelitic infection in the first days of life The eight other cases were giant cell tumours of a femoral condyle in six cases of a tibial condyle in two cases

Resection reconstruction of a femoral condyle

By a long antero medial or antero lateral incision the patella and the quadriceps tendon are exposed

A muscular pedicle is separated about 3 cm wide at the inferior border of the vastus medialis or lateralis preserving as many vessels as possible from the supracondylar portion of the femur to the lateral border of the patella (Figures 1 and 2)

The patella is then separated from the quadriceps tendon along its superior lateral or medial and inferior borders keeping 3 to 4 mm clear from the bone to spare the circular artery supplying blood to the patella through an anterior subaponeurotic network.

The femoral condyle is then exposed and can be removed en bloc with the tumour by cutting the femur with an oscillating saw in a median or paramedian sagittal plane and transversally at the upper limit of the lesion

The patella is then prepared its anterior superficial aspect will be used as articular surface its curvature is very similar to the condyles and the preserved tendinous fibres will play the role of the cartilage Its medial (or lateral) aspect as well as its deep articular surface are freshened

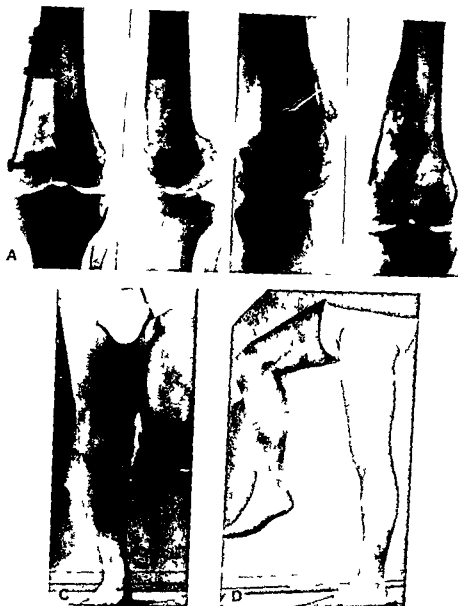


Figure 4 Case 3 Male 31 years Giant cell tumour of medial fem ral condyle A X ray after reconstruction by pedicled patella tibial graft and cancellous grafts B X ray 7 years post op C–D Mobile and stable right knee

The patella must be brought in continuity with the other condyle at the same level as was the removed condyle and firmly fixed there by one or two long screws

The gap between the patella and the femoral shaft if small can be filled by bone chips taken from the iliac crest If it is large it is preferable to use either

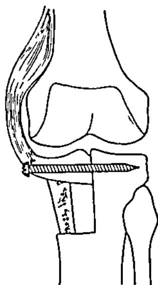


Figure 5 Diagram of reconstruction by patella after resection of a tibial condyle

a massive homograft or combined cancellous graft and cortical tibial graft (Figure 2) The grafts must be firmly fixed by screws

Finally the gap in the quadriceps is closed using the large aponeurotic tendon of the rectus femoris easy to isolate in the muscle the aponeurotic flap turned down is fixed to the patellar ligament to the remaining expansion of the vastus and to the femoral fascia (Figure 2)

After careful hemostasis and closure of the superficial layers a compressive bandage is applied A posterior plaster splint prevents excessive flexion but is removed every day from the first post-operative day for active flexion and supported extension exercises

At the end of the first week, active oscillating movements in the standing position are prescribed Weight bearing is delayed until the end of the third month

Resection reconstruction of a tibial condyle

The operative technique is similar as far as the approach and isolation of the patella are concerned But after resection of the tibial condyle the p tella is placed horizontally with its articular surface upwards in normal relationship with the femoral condyle.

RESULTS

In all eleven cases the postoperative course was simple No infection occurred Mobility was preserved in all cases to 90 or more Stability in extension was good some lateral movement appeared in flexion

Table 1 Reconstruction of the knee aft

Cases	Age	Lesion	Condyle	Technique
1	M 33	War wound	Fem	Pedic. patella + cancellous gra
2	M 19	War wound	Fem	Pedic patella + cancellous gra
3	M 31	Giant cell tumour	Fem	Pedic. patella + tibial graft + cancellous graft
4	M 56	Open comm fracture	Fem	Pedic patella + cancellous gra
5	M 57	Giant cell tumour	Fem	Pedic patella + homograft + plate
6	M 26	Giant cell tumour	Fem	Pedic patella + homograft
7	M 25	Giant cell tumour	Fem	Pedic patella + homograft + tibial graft
8	F 34	Giant cell tumour	Fem	Pedic patella + homograft
9	F 6	Osteomyelitis	Fem	Pedic patella
10	F 32	Giant cell tumour	Tibial	Pedic. patella + homograft

Function was excellent The three first cases reviewed after 23 22 and 11 years can walk as long as they like run and ski

In two cases of reconstruction of the medial femoral condyle some varus deformity appeared 6 years after the operation in one case and 15 years postoperatively in the other Tibial corrective osteotomy was performed in both cases with good result

The results we have reported (Table 1) show that the patella plays the role it is supposed to the living articular surface stands the test of time (more than twenty years in two cases) The quadriceps strength is only slightly diminished

This operation appears as useful in some traumatic destructions of

tion of femoral or tibial condyle

ollow up (years)	Result		
	Mobility	Stability	Observation
21	Very good	0–100	Can run – ski
20	Very good	3–80	Varus deformity – tibia osteotomy can walk any distance, no pain
11	Good	5–90	Varus deformity corrected by tibial osteotomy can ski any distances
2	Very good	5–90	Walks with one cane
4	Good	5–40	Walks 1 km no limp
3½	Good	0–120 After reoperation	Walks any distance. No limp – works standing
2½	Good	0–90	No pain no limp back to work
3	Good	0–85	Slight limp Occasional pain
1½	Some laxity	0–60	Walks with a brace
1½	Good	0–125	No pain – no limp

a condyle in an agenesis of a femoral condyle after newborn osteomyelitis but mostly in giant cell tumours these tumours can be removed "en bloc provided they do not transgress the middle sagittal plane of the bone with preservation of the joint function No recurrence of the *tumour occurred in the severe cases* where this technique of removal was used

SUMMARY

A technique is presented for reconstruction of a femoral or a tibial condyle using the patella maintained alive by a musculo vascular pedicle This operation used in eleven cases after traumatic destruction

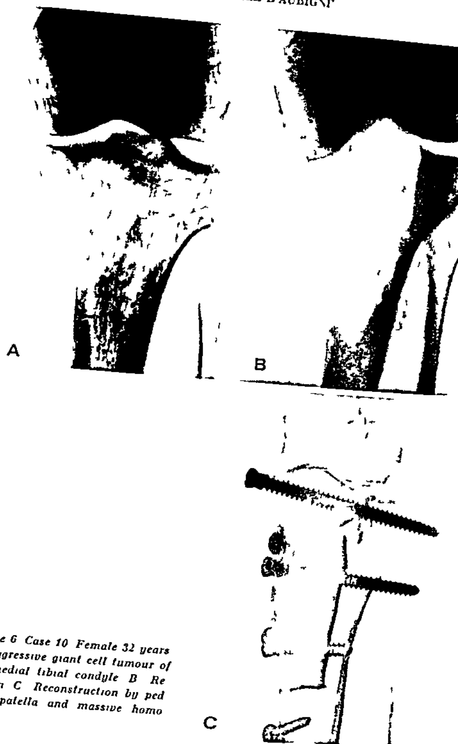


Figure 6 Case 10 Female 32 years A Aggressive giant cell tumour of the medial tibial condyle B Resection C Reconstruction by pedicled patella and massive homograft

of a condyle or surgical removal for tumour has given satisfactory results with preservation of knee stability and mobility Follow up up to 23 years

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SOLITARY CYSTS OF THE TALUS

Report of Two Operated Cases

HENNING PAABY

Accepted 9 iv 73

Solitary cysts of the talus are rare Ogden & Griswald (1972) have recently submitted one case in their opinion the first one on record Below two cases of solitary talar cysts will be described and the aetiology briefly discussed

Case 1 A 64 year old male History of left lateral malleolar fracture treated with a plaster cast in 1959 Ever since intermittent pain in the left ankle increasing during the 6 months preceding admission on 17 November 1969

X *rays* including tomography revealed a large cavity in the talus beneath the tibial aspect of the joint surface with canal like communication to the ankle joint Operation on 19 November 1969 Anterolateral approach to the talocrural joint and neck of the talus The cartilage in the medial part of the talar articular surface was slightly depressed but intact No communication to the bony cavity was visible It was opened by square osteotomy on the neck of the talus and was found to contain a bluish capsule and a gelatinous mucoid fluid The cavity was emptied and packed with chips of cancellous bone Non weight bearing in a plaster cast for 12 weeks

Microscopic examination Lamellar fibrillar connective tissue loose meshed no epithelial lining and in one site a mesothelial like layer of cells No inflammatory changes Mild myxomatous transformation of the connective tissue ground substance Micr diagn Synovial cyst of bone

Follow up 12 February 1973 3 years after the operation Symptom free Radiographic evidence of healing

Case 2 A 42 year old male History of torsion trauma to the left ankle joint in 1967 treated with supporting bandage Since then pain and fatigue in the ankle joint on walking increasing during the year preceding admission on 9 February 1970

X *rays* revealed a bean sized cyst in the central part of the talus beneath the fibular corner of the joint surface

Operation on 11 February 1970 through an anterolateral approach to the talocrural joint The cartilage over the cyst had become damaged and presented itself as a small semi detached body It was removed and through the 5 × 5 mm opening



Figure 1 *Tomographic X ray in Case 1*



Figure 2 *Tomographic X ray in Case 2*

the cyst was scraped with fine instruments and packed with chips of cancellous bone Non weight bearing in plaster cast for 8 weeks

No micr examination

Follow-up on 12 February 1973 3 years after the operation Symptom free. Radiographic evidence of healing

DISCUSSION

Ogden & Griswald (1972) emphasized the extreme rarity of unicameral cysts in the short bones Neer et al (1966) found among 175 bone cysts only 5 in the calcaneus Garceau & Gregory (1954) among 300 cases 9 in the calcaneus Aegerter & Kirkpatrick (1968) among 89 cases one in the tarsal scaphoid A developmental anomaly an abnormal aberrant remodelling of bone with preponderance of the osteolytic process or blocking of the drainage of interstitial fluid have been suggested as aetiological factors in unicameral cysts in children (Garceau & Gregory 1954 Whalen et al 1971 Cohen 1960) Neer et al (1966) have emphasized that cysts of the short bones differ in their course from unicameral cysts in the long bones The aetiology of the present cysts in the talus seems to have been traumatic as in the synovial solitary cysts of bone mentioned by others (Dashefsky 1971 Crane & Sarano 1967 Stadil & Paaby 1970) Through traumatic osteochondral fractures syn

ovial fluid may be pressed into underlying bony tissue leading to cyst formation (Campbell Golding 1966) in accordance with the considerable increases of intraarticular pressure demonstrated by Dixon & Grant (1964) in knees during weight bearing O Donoghue (1966) does not mention development of cysts following osteochondral fractures and Davidson et al (1967) found only one case of incipient cyst formation among 21 cases of osteochondral fractures in the ankle joint Changes similar to osteochondritis dissecans may also result from osteochondral fracture (O Donoghue 1966 Bang Rasmussen 1945) In the present two cases this aetiology seems likely in view of the history X ray findings and histological findings in one of the cases

Alldredge (1942) has pointed out that solitary cysts of weight bearing bones are not cases for a temporizing treatment but should be emptied and packed with bone chips as was done in the cases reported by Ogden & Griswald (1972) and Dashefsky (1971) The indication for operation has been partly to prevent collapse of a bone with cysts of the named size probably resulting in incongruence and secondary osteoarthritis, and partly to relieve pain

SUMMARY

Two operated cases of solitary cysts of the talus are submitted The aetiology and treatment are discussed

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TOE BLOOD PRESSURE IN PERIPHERAL ARTERIAL DISEASE

Quantitative Evaluation of Occlusive Process Localized Mainly in the Arteries in Lower Leg and Foot

P HOLSTEIN & P SAGER

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In patients with obliterative arterial disease of the legs the blood pressure distal to the occlusion is decreased and measurement of the distal blood pressure yields information about the presence and the severity of the occlusive process Various techniques are available Calf plethysmography has been used in measuring the systolic blood pressure on the thigh (Dahn 1965 a b) The Doppler shift ultrasonic detector allows measurement of the blood pressure as distal as on the ankle (Strandness et al 1966 Carter 1969 Bollinger et al 1970 Yao et al 1969 Thulesius 1971) and by using a mercury in silastic strain gauge detector Gundersen & Lassen (1970) and Carter & Lezack (1971) measured the blood pressure on the toes The strain gauge technique has been used in this laboratory for some years and a multisegmental procedure as described by Gundersen (1972) and Bell et al (1973) has been adopted

In this communication the value of assessing a low toe blood pressure is demonstrated in patients where the occlusive process is localized so distally that the systolic blood pressure on more proximal levels including the ankle is normal or only slightly decreased

METHOD

The systolic blood pressure was measured on the first toe on the ankle on the calf and on the thigh The method has been described in detail elsewhere (Gundersen 1972 Nielsen et al 1972) and here only a brief description will be given

A 24 mm wide cuff was fitted on the great toe A commercially available mercury in silastic strain gauge balanced on a Wheatstone bridge as described by Hallböok et al (1970) and connected to an ECG writer (Mingograph Elema Schonander Sweden) was placed around the tip of the toe The veins of the toe were emptied of blood by compressing manually the pulp of the toe and the cuff was suddenly inflated to suprasystolic pressure level The cuff pressure which was recorded on the writer was released at a rate of 1–2 mmHg per second and at a certain cuff pressure an increase of the tracing recorded, indicated that blood escaped under the cuff and filled the distal arterial tree This pressure was taken to be the systolic blood pressure of the toe

The procedure was carried out three times and at each measurement the brachial systolic blood pressure was measured by the standard auscultatory method The mean of the distal pressure values and the mean of the systolic brachial pressures were calculated In general the distal blood pressure was measured on both legs at the same time Then the blood pressure was measured on the ankle level by using a 12 × 28 cm cuff placed with the distal edge just above the malleoles On the calf and on the thigh the systolic pressure was measured using a 18 × 60 cm cuff placed on the most voluminous part of the calf and as proximal as possible on the thigh respectively For detection of volume expansion during ankle and calf pressure measurement the toe strain gauge was again used whereas the measurement on the thigh was carried out with the detector a long strain gauge placed on the calf

All measurements were performed with the patients in the supine position The legs were carefully supported by sandbags and during the thigh measurements a sandbag was also placed under the patients knees to prevent the strain gauge on the calf from touching the couch Room temperature was 26 0 ± 1 Celcius and skin temperature was 27 0–31 6 C as measured on the pulp of the first toe

MATERIAL

The material consisting of 17 limbs of nine patients was selected on the criteria of a low systolic blood pressure on the great toe and a normal or only slightly decreased blood pressure at the level of the ankle In normal subjects the systolic ankle blood pressure values are above the brachial arm blood pressure the average difference between ankle blood pressure and arm blood pressure being + 20 mmHg ± 20 mmHg (mean ± 2 5 s d.) In younger subjects (17–31 years) an ankle—toe difference of 43 mmHg or more is significant of arterial lesion with a confidence of 99 per cent and in elderly patients (43–57 years) a gradient of 64 mmHg is the criterion (Nielsen et al 1972)

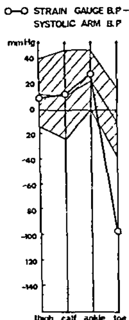
The clinical data are listed briefly in Table 1 together with the ankle and toe systolic pressures the corresponding brachial systolic pressures and the ankle toe differences as corrected for alterations in systolic brachial pressures All pressures listed are the mean values of triplicate measurements. The blood pressure measured on the calf and on the thigh were normal in all limbs and these figures are not listed There were eight male patients and one female The ages ranged from 29–69 years (mean 54 years) According to the clinical criteria outlined by McPherson et al (1963) three patients had thrombo angiitis obliterans and six patients arterio

Table 1

Case no	Age sex	Leg	Clinical data	Pulsation in dorsal pedal artery	Pulsation in posterior tibial artery	Systolic ankle BP	Systolic arm BP	Systolic toe BP	Systolic arm BP	Ankle BP† −toe BI
1	46 ♂	L	Slowly healing ulcer on the great toe Intermittent claudication	—	—	124	112	36	111	87
		R	Slowly healing ulcer on the great toe Intermittent claudication	—	—	127	112	36	111	90
2	62 ♂	L	No symptoms	—	+	173	162	95	150	66
		R	Intermittent claudication	—	+	161	162	66	150	83
3	68 ♂	L	No symptoms	+	+	200	171	98	176	107
		R	Slowly healing ulcer on the great toe	+	+	177	171	34	176	138
4	29 ♀	L	Slowly healing ulcer on the foot	+	—	141	131	54	135	91
		R	(Proximal arterial occlusion – no symptoms)							
5	69 ♂	L	No symptoms	+	—	233	219	155	216	75
		R	Slowly healing ulcer on the foot	+	—	216	219	51	216	162
6	72 ♂	L	Chronic ulcer on the foot Intermittent claudication	—	—	146	164	44	164	102
		R	Intermittent claudication	—	—	154	164	52	164	102
7 §	46 ♂	L	Gangrene of the great toe Rest pain	—	—	100	129	25	128	74
		R	No symptoms	—	—	140	129	37	128	102
8 §	54 ♂	L	Chronic ulcer on the great toe Rest pain	+	—	149	124	36	136	125
		R	No symptoms	+	—	155	124	73	130	88
9 §	39 ♂	L	Gangrene of the fifth toe Rest pain	—	—	142	130	30	130	112
		R	Gangrene of the first toe Rest pain	—	—	160	130	23	130	137

Diabetes mellitus § Thromboangiitis obliterans † Corrected for change in systolic arm BP

Figure 1 Systolic blood pressure measured at four different levels including the great toe (case no 8 left leg) Normal values (mean ± 2.5 s d) are shown as the hatched area Arm blood pressure is taken as a zero reference point



sclerosis obliterans Two of the patients with arteriosclerosis obliterans had diabetes mellitus

Three limbs suffered from toe gangrene and severe rest pain Seven limbs had chronic non healing or slowly healing ulcers localized in the toes or forefoot in two cases associated with intermittent claudication Two limbs suffered from intermittent claudication only and five limbs were without symptoms two of these had earlier had slowly healing toe ulcers In the five limbs without symptoms the disease was detected during evaluation because of symptoms from the contra lateral leg In two limbs pulsations could be felt in both pedal arteries and in seven limbs pulsations could be felt in either the posterior or the anterior tibial artery In eight limbs no pedal pulses could be felt In all limbs normal pulsations could be felt in the femoral artery at the groin

The presence of distal arterial occlusive processes was confirmed by angiography In all limbs there was occlusion of one or two main arteries on the calf All feet had decreased arterial supply six feet were supplied only by collaterals eleven feet were supplied only by the anterior or the posterior tibial artery and this last main arterial pathway was furthermore occluded on the foot in three limbs Three limbs had a slightly decreased ankle blood pressure. In one of these limbs the last patent artery on the calf was occluded just proximal to the ankle and in two limbs there were stenoses in the thigh arteries in addition to the distal occlusions

Stenoses of the femoral arteries were also found in two limbs with a normal ankle blood pressure but in none of the limbs were there arterial occlusions proximal to the division of the popliteal artery

As an example of the distal arterial lesions the pressures from case no 8 the left leg are plotted on a diagram showing the normal pressure variations (mean



Figure 2 Angiography (case no 8 left leg) showing occlusion of the posterior tibial artery (arrow) The peroneal artery is rudimentary Only the anterior tibial artery is patent



Figure 3 Angiography (case no 8 left leg) showing the patent anterior tibial artery Only the first segment of the dorsal pedal artery is intact Occlusions are indicated by arrows The posterior tibial artery is not visualized (see Figure 2)

± 2 5 s d) with the brachial systolic pressure taken as a zero reference point The striking decrease in pressure from the ankle to the great toe is apparent The arterial lesions in this leg are shown in Figure 2 and Figure 3

The toe pressures correlated to the clinical condition In three limbs with gangrene the toe pressures were 23–30 mmHg (mean 26 mmHg) and in seven limbs with chronic or slowly healing ulcers the pressures ranged from 34–54 mmHg (mean 42 mmHg) Two limbs with only symptoms of intermittent claudication had toe pressures of 52 and 66 mmHg and the five limbs with no symptoms in spite of the distal arterial lesions had toe pressures ranging from 37 to 155 mmHg

DISCUSSION

Several authors (Strandness & Bell 1965 Strandness et al 1966 Carter 1969 Yao et al 1969 Bollinger et al 1970 Thulesius 1971) have in recent years reported on the ankle blood pressure as a valuable quan

titative measure of obliterative arterial disease The present communication was stimulated by the occasional finding of a limb with a normal ankle blood pressure and a low toe blood pressure pointing to an arterial lesion localized very peripherally These lesions which in all limbs were verified by angiography were often difficult to recognize by the clinical examination especially when pedal pulses could be felt Ischemia should always be suspected in case of a chronic pedal ulcer and the diagnosis may certainly be verified by angiography But a clear cut quantitative diagnosis is easily obtained by measuring the blood pressure on the ankle and toe Furthermore the healing of skin lesions in areas of arterial insufficiency is strongly correlated to the local blood pressure (Carter 1973 Holstein 1973) and thus the pressure measurement is the key to the proper therapy

An abnormal pressure drop between ankle and toe suggests arterial lesion in the arteries of the foot or digits This was confirmed by angiography but in all limbs there was also obliteration of one or two main arteries in the calf A normal blood pressure measured on the ankle by the strain gauge technique may thus be maintained by one patent artery either the posterior or the anterior tibial artery or the peroneal artery It should be emphasized that the present method of measuring the distal blood pressure cannot detect occlusion localized in arterial side branches as long as a main arterial pathway is intact Similar observations with regard to peripheral occlusive processes and a large ankle toe difference have been reported by Carter & Lezack (1971)

Distal arterial occlusions are not necessarily associated with symptoms Five legs in this series were without symptoms and did not even suffer from intermittent claudication A decreased activity because of symptoms from the other leg in these patients should be mentioned as a possible explanation for the lack of pain during exercise However these patients often become completely free of symptoms and fully active if skin lesions heal and a decreased activity is therefore not the reason for the lack of pain during walking It is worth pointing out that patients with distal arterial lesions may present a chronic or slowly healing skin lesion as the only sign of disease In spite of obliteration of one or two calf arteries one patent artery is apparently sufficient to supply the calf muscles during walking and the blood supply to the foot may be sufficiently maintained by collaterals

A wide range of pressures were found in the legs without symptoms In the case of mild disease the blood pressure on the toe is only slightly decreased and when the systemic blood pressure is high the toe blood

pressure may also be quite high Low pressure on the toe is caused by severe occlusive process but may also exist in mild disease if the systemic blood pressure is low As is evident from this series it is the limbs with a low toe blood pressure that may present impaired wound healing

The distal blood pressure can be measured by various methods and some of these require very little equipment By the flush technique (Carter 1969) the systolic blood pressure is detected by watching carefully the skin during stepwise deflation of the cuff A pink colour and a swelling of veins indicates that blood is escaping under the cuff We prefer the strain gauge technique because the pressure is recorded objectively by a curve The technique is suitable for bedside use being quick and simple The sensitivity of the detector is quite high and even minimal volume expansion is registered A wide range of pressures from about 5 mmHg to over 200 mmHg can be picked up and the values obtained are well correlated to the clinical condition (Gundersen 1972) and angiographic findings (Carter & Lezack 1971 Bell et al 1973) The presence of ulcers even patchy gangrene on the great toe does not necessarily hinder the pressure measurement on this site In addition the pressure values are expressed in *millimeters of mercury*, which is easy to communicate to all members of a medical staff

Occasionally a stiff arterial wall may cause too high a pressure value but this type of error is in general recognized when measuring the blood pressure at more than one level and in cases where a segment of the extremity has shown an unreasonably high pressure value we have found that the artery under the cuff appeared as a calcified tube on a plain X ray On the toe level the transmission of pressure from the cuff to the small digital arteries is probably reliable Solitary high pressure values at this distal level have not been observed

It should be mentioned that pressure measurements should be performed at comfortable room temperature so that the skin temperature on the toes is between 22 and 33 (Celcius) otherwise the recorded values may be too low (Gundersen 1972)

By measuring the blood pressure on the ankle and toe the most threatened part of the extremity is evaluated and thus these measurements are valuable for all patients with obliterative arterial disease of the limbs In this paper we have commented on the *distal* arterial occlusion because the toe blood pressure gives a quantitative diagnosis which otherwise is difficult to obtain

SUMMARY

Measurement of the ankle blood pressure fails to reflect occlusive arterial disease localized in the arteries in the lower leg and foot and a clinical assessment of the disease may be difficult A quantitative diagnosis can easily be obtained by measurement of the toe blood pressure Measurements in 17 limbs with such distal obliterative arterial processes are reported

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LOWER EXTREMITY AMPUTATION IN UPPSALA COUNTY 1947–1969 INCIDENCE AND PROSTHETIC REHABILITATION

FOR HIERTON & URBAN JAMES

Accepted 1 iv 73

In published reports of statistical nature on amputations and rehabilitation the data given vary considerably This seems to be due to the fact that some figures have been based on the total number of amputations during a certain period whereas other estimates have been made from the number of amputees still alive in a given population or from the number of patients supplied with a prosthesis In the latter case trauma predominates as the reason for the amputation Such patients usually have a long expectation of life and have higher demands on prosthetic function and service Totally however the great majority of amputations are performed for ischaemia and gangrene There is general agreement that the frequency of obliterative arterial diseases as a reason for amputation is on the increase and it is especially the higher age groups that are affected (Alffram & Holmquist 1961 Hansson 1964 Tibell 1971 Committee on Prosthetic Orthotic Education 1971 *Hierton & James 1972)*

We here present a survey of all amputations performed in our own county during certain years in order to obtain current figures elucidating the frequency cause and level of amputation the age at amputation and survival time and the time interval between amputation and fitting with a prosthesis

MATERIAL AND DEFINITIONS

The survey is based on amputations performed in Uppsala County in 1947 1957 1967 1968 and 1969 The information was obtained from case records from the Uppsala University Hospital Enköping Hospital Samaritan Hospital in Uppsala and Tierp Hospital i e all hospitals in the county

Above knee amputation refers to the levels between knee and hip disarticulation

Table 1 Occurrence of amputations in Uppsala County during the years in question The amputation frequency is given totally per 100 000 of the whole population and also for vascular disease per 100 000 inhabitants > 60 years of age

Uppsala county year	No of amputations total	frequency per 10^5 inhabitants	due to other reasons than vascular disease	due to vascular disease	frequency per 10^5 inhabitants > 60 yrs
1947	16	10 7	6	10	43
1957	19	11 5	5	14	49
1967–69 (mean value)	34	17 1	2 3	31 3	85
Change	+ 110 %		— 60 %	+ 213 %	

Below knee amputation refers to the levels from above the ankle joint to just below the knee Amputation of the foot and toes is thus not included

Fitting of prostheses has been in the hands of Een & Holmgrens Ortopediska AB whose workshop in Uppsala and service have become attached by contract to the University Hospital The gait training of the patients took place at the Amputee Training and Research Unit *(Gasl olan)* of the Department of Orthopaedic Surgery this Unit is localized in the immediate vicinity of the Orthopaedic Workshop

INCIDENCE 1947 1969

In 1947 when the population of Uppsala County was 150 000 16 lower limb amputations were performed. The corresponding figures for 1957 were 164 000 and 19 respectively In the three years 1967–1969 an average of 34 lower limb amputations per year were performed on a population of 196 000 Thus the increase in the number of amputations was considerably larger than the corresponding increase in population (Table 1) It was mainly the proportion of persons over 60 years of age that had increased in the county and the increase in the number of amputations was mainly found in this part of the population

If we look at the indications for amputation it is as expected the vascular diseases that predominate As seen in Table 1 there were 10 amputations for vascular disease in 1947 14 in 1957 and an average of 31 3 per year in the three years 1967–1969 Simultaneous with this marked increase (213 per cent) other reasons for amputation had decreased in frequency If the total number of amputations for the three compared periods is placed at 100 per cent as in Figure 1 the proportion of reasons for amputation other than vascular diseases decreased from 40 to 7 per cent

AMPUTATION FOR ISCHAEMIC DISEASE 1967–1969 (Tables 2–6)

Below knee amputation was performed in 60 per cent and above knee in 40 per cent. In the great majority of cases (84 per cent) the amputation was unilateral. Bilateral amputations thus occurred in 16 per cent Of all amputations 60 per cent

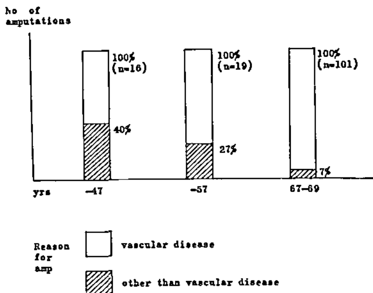


Figure 1 The proportion of vascular disease and conditions other than vascular disease as the reason for amputation in 1947, 1957 and 1967–1969

occurred in diabetics. In these patients amputation below the knee was more common than above knee amputation (Table 2).

Diagnosis, level and age

The youngest diabetics were 37, 43 and 48 years of age and had had their diabetes for 30, 22 and 12 years respectively. They also had other severe manifestations of diabetes at the time of amputation. The mean age of the diabetics at the time of amputation was 72 years (Table 3).

The two youngest patients among the non diabetics were one patient with Buerger's thromboangiitis obliterans—a 36-year old man who sustained bilateral amputation and a 46 year old man with severe arteriosclerosis obliterans. The mean age at amputation of the non diabetics was 76 years (Table 3).

If the patient with Buerger's disease is excluded, the mean age is raised to 77 years.

The mean age of the above knee amputees was 77 years and of the below knee amputees 71 years (Table 3).

Survival

Just over half of the patients with amputations due to vascular disease were alive one year after the operation (Table 4).

Of the diabetic amputees 30 per cent died within 3 months and 61 per cent lived for more than one year; of the non-diabetic amputees 24 per cent died within 3 months and 44 per cent lived for more than one year (Table 4).

Table 2 Amputations for vascular disease 1967–1969

		Amputations	Per cent
Sex	women	53	56
	men	41	44
Diagnosis	diabetics	56	60
	non diabetics	38	40
Level	above knee	38	40
	below knee	56	60
Laterality	unilateral	79	84
	bilateral	15	16

Revision and reamputation

A secondary operation was three times as common after below knee as after above knee amputation At reamputation one third of the below knee amputees lost the knee joint whereas half of the above knee amputees lost the hip joint

The reason for revision and reamputation was usually necrosis of the skin flap of varying degrees of severity or secondary infection In one case rupture of the wound necessitating a higher amputation level occurred after knee joint disarticulation With regard to both local revision and reamputation at a higher level the frequency of diabetes was approximately the same as among the total number of amputations 71 per cent of the patients who underwent a secondary operation were fitted with a prosthesis later—83 per cent after revision of the wound with retention of the primary amputation level and 63 per cent after reamputation

Table 3 Amputations for vascular disease 1967–1969

Diagnosis and level	No	M (SD) range
Diabetics	56 (60 %)	72 (11) 37 – 89
Non diabetics	38 (40 %)	76 (12) 36 – 93
Above knee	38 (40 %)	77 (10) 36 – 91
Below knee	56 (60 %)	71 (10) 43 – 93

No = number of patients
M = mean age years
SD = standard deviation

Table 4 Amputations for vascular disease 1967–1969

Survival months	Diabetics	Non diabetics	Total
< 3	17	9	26
3–12	5	12	17
>12	34	17	51
Total	56	38	94

Prosthetic rehabilitation after unilateral amputation (Table 5)

Approximately half of the patients were fitted with a prosthesis 66 per cent of the below knee amputees and 23 per cent of the above knee amputees

Concerning the time interval between amputation and fitting of the prosthesis it was found that half of the below knee amputees were fitted within 2 months whereas none of the above knee amputees were fitted within this short time Within 2–4 months about 80 per cent of the unilateral below knee amputees who were fitted had received their final prosthesis The corresponding figure for the above knee amputees was about 70 per cent The remaining 20 per cent of the below knee amputees and 30 per cent of the above knee amputees who were fitted with a prosthesis needed more than 4 months

An important factor in the fitting of the prosthesis was the patient s ability to put on and take off his prosthesis himself Of 35 unilateral below knee amputees supplied with a prosthesis only 7 needed the help of another person Of the 6 unilateral above knee amputees fitted with a prosthesis no fewer than 5 needed help for putting it on

Thirty of the 35 unilateral below knee amputees fitted with a prosthesis were able to walk with the prosthesis without help of another person primarily whereas only 3 of the 6 above knee amputees were able to do so The number of patients who could walk without the support of another person six months after the primary fitting was for the below knee cases reduced to 26 and for the above knee cases to 3 (deteriorated general condition disease or death)

Bilateral amputation due to vascular disease

In this category there were more diabetics than non diabetics The time interval between the first and second amputation can be seen in Table 6

The diabetic patients who on the whole were somewhat older showed rather more varying and longer intervals than the non diabetics The number are small however and the differences are not statistically significant

Fewer than half of the patients who underwent bilateral amputation for vascular disease were fitted with a prosthesis and had some gait training Two bilateral below knee amputees were fitted with a prosthesis within two months Both developed a good walking capacity and needed no help with putting on the prosthesis. They regained walking ability to a large extent The combination of above and below knee amputation resulted in fairly good function in 4 out of 9 cases whereas only one of the 3 patients with amputation at the thigh level on both sides for vascular disease had any appreciable value from his prostheses

Table 5 Prosthetic rehabilitation of unilateral above knee and below knee cases amputated for vascular disease 1967–1969

Level	Patients	Fitted with prosthesis	Time lag between amp and prosthetic fitting (months) <2	2–4	>4	Able to put on prosthesis without help	with help	Prosthetic walking ability primarily without help	primarily with help	6 months later without help	6 months later with help	Use of prosthesis after primary fitting
Above knee	26 100 %	6 23 %	–	4	2	1	5	3 12 %	3	3 12 %	1	3 12 %
Below knee	53 100 %	35 55 %	18	10	7	28	7	30 57 %	4	26 49 %	2	28 53 %
Total	79 100 %	41 52 %	18	14	9	29	12	33 41 %	7	29 37 %	3	31 39 %

Table 6. Bilateral amputations for vascular disease 1967–1969. Time between amputation on first and second extremity and mean age for patients with and without diabetes

Years	Diabetics No.	Non diabetics No.
< 1	3	2
1–3	2	2
4–9	3	1
> 9	2	–
Total	10 67 %	5 33 %
Mean age yrs	76 (66–88)	63 (36–79)

If one 36 year old patient with Buerger's disease is excluded, the mean age is 69 years (56–79).

DISCUSSION

The increase in the number of lower limb amputations between 1947 and 1969 which we have found in this investigation is in agreement with the reports of Hansson (1964) from Gothenburg and Tibell (1971) from Malmo. The growing proportion of elderly persons in the population, together with an increased frequency of ischaemic manifestations in these persons, is responsible for the raised amputation frequency. Amputations performed for other reasons, such as trauma and infection, have decreased in significance due to improved methods of treatment of open fractures and infectious conditions.

With regard to obliterative arterial disease, it is true that arterial reconstructive methods can sometimes save an extremity from amputation, but among patients of higher ages with their often very extensive and advanced vascular changes, occasional cases successfully treated by this kind of surgery have had no effect on the statistical situation. *It is important*, however, that an amputation shall not always be regarded as a therapeutic failure. It may, on the contrary, constitute *beneficial treatment at a certain stage* of the patient's severe arterial disease—it can relieve him of pain and stinking gangrene and thereby rapidly *improve his general condition*. With modern postoperative treatment and prosthetic equipment even the very elderly patient may—with *certain prerequisites*—*regain some degree of function* and walking ability. Under optimum conditions amputation and subsequent

training with the prosthesis should be integrated and should thus be regarded as a reconstructive not destructive measure

Previously most surgeons recommended above knee amputation for the treatment of gangrene due to obliterative arterial disease They chose a high level in order to be sure of primary healing Once amputation had been accomplished and wound healing had occurred little interest remained for the problems involved in fitting a prosthesis and training the patient to independence This lack of interest regarding the late post surgical period could easily be understood—the rehabilitation potentials for the elderly AK amputees were indeed not very encouraging The fact was that very few elderly thigh amputees became independent walkers This is general experience

In the statistical study from Gothenburg from 1947–1969 Hansson (1964) found that above knee amputation was more common than amputation below the knee The same has been reported by other Scandinavian authors (Jansen 1960 Widolf 1961 Fellander et al 1962 Lundholm 1963 Hallen & Hult 1964 Lindholm 1964 1965 Vankka 1967 Lindahl & Bolund 1969)

Regarding rehabilitation potentials following amputation general agreement has been reached that the integrity of the knee joint is one of the most important single factors According to a statistical survey in 1965 made by the The National Board of Health and Welfare the number of above knee amputations performed in the Stockholm and Uppsala areas was about the same as the number of below knee amputations In the present survey in Uppsala County in 1967–1969 the below knee amputations were found to be in the majority It is hoped that this trend will continue We have put much emphasis during recent years on the concept that every effort should be made to preserve the knee joint

Furthermore the principle of rehabilitation—restoration to an optimum level of function in the shortest period of time—has gained recognition and active interest has been focused on all aspects of the treatment of amputation patients (Hierton et al 1967) Gradually the below knee amputation has been accepted as the level of choice for gangrene Even a short stump can be successfully fitted with a modern total contact prosthesis More attention has also been directed towards the correct surgical technique for the amputation procedure and a careful handling of the tissues It has been shown that an anterior flap should be avoided Use of the long musculocutaneous posterior flap is safer in ischaemic cases Suction drainage prevents haematoma Careful

postoperative dressing—rigid or elastic—prevents oedema and facilitates ambulation It has been shown that early prosthetic fitting stimulates all persons involved Weight bearing on the non healed ischaemic stump should however be avoided We usually apply a plaster post operatively to prevent flexion contracture and allow the patient to be ambulatory on crutches as soon as possible In gait training suitable below knee amputees are given a temporary prosthesis with weight bearing on the ischial tuberosity and leaving the below knee stump unsupported but protected by an elastic stocking (Hierton 1970 Hierton & James 1972)

In spite of the fact that additional handicaps are common among elderly amputees often rendering them unsuitable for any gait training or prosthetic fitting there is a considerable group of patients who will benefit from a well organized orthopaedic rehabilitation programme This should be characterized among other things by a short time lag between surgery and fitting of the prosthesis

With modern techniques for making the prosthesis there should be practically no waiting period for the patient from the time the measurements are taken until the prosthesis is ready for the first fitting In the present study of patients with amputations due to ischaemia we found that about 50 per cent of the unilateral below knee amputees who got a prosthesis were supplied within 8 weeks postoperatively and 80 per cent within 16 weeks For the unilateral above knee amputees a longer time postoperatively was necessary For 70 per cent of them it took 16 weeks None of the above knee amputees were fitted within 2 months

SUMMARY

A short survey is given of a statistical study on the incidence of lower limb amputation in Uppsala county 1947–1969 Amputations for vascular disease showed a marked increase in number

In spite of the fact that additional handicaps are common among elderly amputees often rendering them unsuitable for any gait training or prosthetic fitting there is a considerable group of patients who will benefit from a well organized orthopaedic rehabilitation programme

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THE CONNECTION

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The functions provided by the connection between an amputee and his artificial leg are primarily transfer of weight bearing loads to the ground through the distal portion of the prosthesis the transmission of power from the body to the prosthesis for actuation and control of the prosthesis and the provision of suspension of the prosthesis when it is not in contact with the floor or ground

The only successful way of providing these functions to date is by means of a tubular cup like receptacle known as the socket that encases the amputation stump Sometimes all or part of the suspension function is provided by straps over other parts of the body

No single factor is more important in lower limb prosthetics than the relationship between the amputation stump and the socket Proper fit has yet to be defined quantitatively But the most sophisticated mechanical components are of little use when the artifial leg is attached to the patient so loosely that control is inefficient Conversely when in an effort to provide stability the socket fits so tightly as to restrict blood flow in the stump the prosthesis must soon be abandoned

The most significant contributions of the American and Canadian research programs in limb prosthetics (Wilson 1970) are considered by many to be socket designs methods of socket fitting and fabrication and principles of prosthesis alignment The outstanding examples are Canadian Plastic Syme s prosthesis and its variants the patellar tendon bearing (PTB) below knee prosthesis and its variants the quadrilateral sockets with and will out suction with and without total contact for above knee amputees and the Canadian hip disarticulation and hemipelvectomy prostheses (Wilson 1968 1969 1970)

The instructions set forth in manuals used in educational programs when followed closely by skilled prosthetists result in adequate prostheses for patients without other complicating factors However com

plicating factors which tax even the most competent prosthetists are often present and if, for no other reasons methods for providing sockets that meet more adequately the demands of all amputees are needed

SOCKET DESIGN

To provide better criteria for socket designs it seems obvious that we need to know a good deal more about the mechanisms of edema and the circulation of body fluids than we do at present One reason we lack knowledge in these areas is that we do not have the means to measure efficiently the pressures between the stump and the socket or the methods of measuring effectively the results of the application of pressure

These problems have been recognized for many years and some efforts though with little useful results have been made in determining the distribution of forces over the amputation stump (Appoldt 1969 1970) Pressure transducers that have been used to date have been either unreliable or used improperly and up to this point few ideas have been set forth in reference to practical ways to measure the effects of pressure on the soft tissues of an amputation stump (CPRD 1972)

Several independent developments have taken place through the years that if combined might lead to relatively inexpensive studies that might in turn lead to improved connections between patient and prosthesis

One of the deterrents to studying the effect of changes in socket shape on the amputation stump has been the cost of making individually tailored sockets and fitting and aligning them with other components to provide prostheses suitable for experimental purposes

The dilatancy technique for taking impressions of amputation stumps has been refined in recent years especially by Germans et al at the Medical Physics Institute in Holland and offers a very inexpensive way of obtaining casts and models of stumps for the production of experimental sockets (CAL 1947 Koster 1972)

The work of Snelson & Mooney (1972) has shown that for practical purposes not only can the time required for lamination be eliminated but a transparent socket as well can be had quite inexpensively by vacuum forming techniques A transparent socket clearly offers the opportunity not only for visual observation but also an opportunity for the investigators to ensure that the pressure transducers are always



Figure 1 Transparent polycarbonate sockets fitted to a bilateral below-knee patient

in the same location and that the socket is in the same relationship with the stump during each trial (Figure 1)

Lightweight inexpensive endoskeletal components for lower limb prostheses that permit all adjustments required for proper alignment are now available commercially (Wilson 1968 1969) so that coupled with dilatancy casting and vacuum forming of sockets a feasible means of providing many experimental socket shapes for the same group of subjects is readily available

A few years ago the pressure transducers considered useful for measuring pressure between the stump and the socket cost more than $300 per unit and the area covered was less than 1 28 cm² There is

some question about the size of the area that will provide a useful measure but certainly 1 28 cm is too small to be practical or desirable even when the pain threshold is not exceeded

An approach not yet tried scientifically is the measurement of forces over components of a segmented socket It would seem that this is a more logical approach than measuring pressures over pinpoint size areas An inexpensive pressure transducer that can be used to measure the force over relatively large areas and thus appears practical in socket research has been developed by Moss Rehabilitation Hospital (CPRD 1972)

Visual observation through a transparent wall of a socket will of course help in observing the outward effects of pressure on the soft tissues of the stump but it would seem that one of the most logical methods available to measure and record these effects is the Thermograph camera (Brand 1969 1970) A complete record of skin temperatures can be made very rapidly by use of thermography without danger or discomfort to the patient Brand in working with leprosy patients has pointed the way for use of this technique

Another development that has been suggested over the years, and one that is gradually being learned about is the use of inflated pads on the inner surface of the socket to provide an adjustable range of pressure Newer materials and more awareness of the way inflated units work coupled with the suggestions given above should make this approach more attractive as time goes on

New sheet plastics that have better properties seem to be introduced rather constantly Yet polypropylene polyethylene and other materials have not been tried thoroughly although they are used in orthoses routinely in some institutions Their combination of flexibility and tensile strength seems to have much to offer when studying the advantages that might be provided by socket walls that have a stiffness gradient—one that becomes more flexible in the proximal direction (Murphy 1960)

SURGERY

It has been stated many times that surgical procedures have a great effect on the stump and the consequent fitting of the socket This of course is true especially in reference to invaginated scars and obviously poorly placed incisions Not so clear are the advantages of myoplasty myodesis and osteoplasty (Burgess 1969 Dederich 1970 Loon 1962 Swanson 1966 Weiss 1971) We all have our clinical impressions but

to date no one has carried out a scientific evaluation of these techniques This is most unfortunate because the means of doing this are available

Not so easy to assess is the idea of skeletal attachment or the connection of the prosthesis directly to the long bone of the amputation stump This idea is not new but if it would be made practical the connection problem for the majority of amputees would be solved and the engineers could devote more time to the design of other mechanisms and components

The problem can be divided into two parts attachment to the bone and the exit through the skin and the superficial soft tissues

The first reference to skeletal attachment came from Germany (Cutler 1945 Murphy 1960) in 1945 but little work seems to have been carried out since then in any place but the United States Esslinger (1970) influenced by Stone s work with the human eye showed that certain Silicone compounds were compatible with both osseous and soft tissues and he had some success with percutaneous plastic strips staying in place along the backs of dogs but did not collect sufficient data to make follow up studies of his techniques attractive Hall used Dacron velour in treating a horse with some success Mooney (1971) has been experimenting with ceramic structures and vitreous carbon as the percutaneous materials

In all of the experiments encouraging results have been obtained It is of course difficult to find human subjects for these kinds of experiments and animal studies leave much to be desired Nevertheless research in skeletal attachment of external prostheses is encouraging and should be supported

SUMMARY

The need for improved designs for sockets for artificial legs is stated and suggestions for research that will lead to more functional connections between the patient and the prosthesis are set forth

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FIBULECTOMY AND RESECTION OF THE PERONEAL NERVE FOR "SHORT TIBIA STUMPS"

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The preservation of even a short tibia stump is of great functional importance to the amputee The proprioceptive sense of the stump for a proper forward thrust of the leg is self evident

The ideal length of a below knee amputation is 12½–17½ cm (Alldredge & Murphy 1968 Gillis 1964 *inter alios*) In very short stumps these authors advise leaving at least the head of the fibula to key the stump in the socket But in amputations shorter than 7½–8¾ cm below the knee joint Alldredge & Murphy (1968) advise removing the fibula completely In such cases the peroneal nerve should be pulled down and resected so that it retracts above the knee

Such a short tibia stump has peculiar problems for a successful fitting of a modern below knee prosthesis They are The stump presents a sloping surface and tends to slip in and out of the socket causing rubbing and friction The areas for weight distribution are limited to the medial tibial surface below the condyle the patellar tendon and the very limited area anterior to the head of fibula on the lateral surface of the stump

The stump end is of no significant value for weight bearing and the anterior crest of the tibia is very sensitive to pressure

The popliteal area adds to the difficulties Limitation of flexion to 70–80 is permissible if the stump should rest safely in the socket The tender areas of the hamstring muscles add to the difficulties

METHOD

Taking into account all these problems connected with a short tibia stump we set before us two principles We have to create a stump with the greatest length possible and with no tender areas for weight transmission in order to put our limb

fitting on a sound biomechanical base and to create a pain free stump for our patients

The first observation was a twenty year old man with a congenital postaxial meromelia of the left leg with considerable shortening and deformation of the foot. After amputation of the leg a patellar tendon bearing prosthesis was fitted without any difficulties on the contrary the wide area on the lateral tibia below the condyle was very convenient for just this purpose.

Surgical technique

The existing scar is excised and the fibula exposed by elongating the incision proximally The head of the fibula and the shaft are sub periostally excised, the peroneal nerve exposed pulled down and severed most proximally The periost and capsula are closed and if necessary the muscle belly of the triceps is attached to the tibia The skin is closed with adequate excision of all scars

A polyethylene tube is used as a drain for 48 hours with a separate stab incision in the middle of the posterior flap A well padded plaster cast finishes the procedure

RESULTS

We operated on 23 patients aged 20–35 years Eighteen patients had an amputation performed after extensive destruction of the foot and leg 3 patients due to sepsis after an open fracture and 2 patients because of congenital post axial meromelias of the leg The tibia stumps varied in length between 4½ and 12 cm All patients had previous unsuccessful trial fittings with different types of prostheses

We wish to illustrate this procedure by some of these patients reports

1 L E Below knee amputation after mine explosion and destruction of the left leg Length of tibia after amputation 8 cm length of fibula 3 cm The popliteal region was covered with an extensive skin graft The patient was fitted with a P T B prosthesis with a thigh corset but could not wear the prosthesis because of pains in the stump end and on the head of the fibula (Figure 1 a)

The fibula was resected together with the peroneal nerve There was no difficulty fitting a Munster type of P T B prosthesis (Figures 1 b–c) The patient is so pleased with his prosthesis that he sometimes plays a game of soccer

2 S I A neuro-vascular injury of the left leg and open fracture of both bones in the upper third of the same leg prompted an amputation below the fracture line Both bones healed with an angulation leaving a stump of 6 cm length with adherent scars on the anterior aspect of the remaining tibia and an extremely prominent fibular head A trial



Figure 1 a Traumatic amputation after mine destruction Length of tibia 8 cm of fibula 3 cm (male aged 31 years)



Figure 1 b After fibulectomy and neurectomy

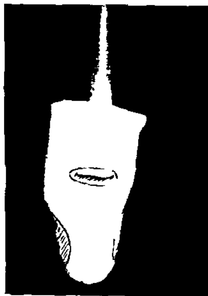


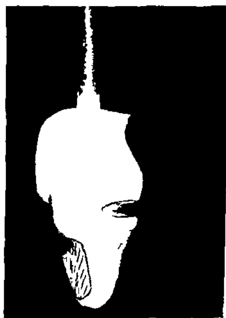
Figure 1 Patellar l g medial and lateral areas of weight bearing



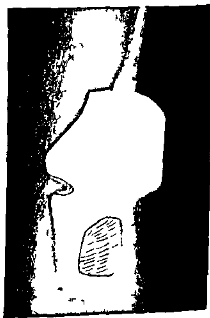
Figure 2 a Amputation after open fracture with loss of bone and neuro vascular injury Length of tibia 5 cm fibula 3 cm (male aged 23 years)



Figure 2 b After fibulectomy and neurectomy



c



d

Figures 2 c 2 d Patellar lig medial and lateral areas of weight bearing

fitting was unsuccessful because of the pain on the fibular head and skin abrasions on the tibia (Figure 2 a)

The fibula was excised together with the peroneal nerve The scar could be partially excised The patient was fitted with a P T B prosthesis and walks without any difficulties (Figures 2 b–c)

3 S E An open double fracture of both bones of the right leg had to be amputated below the upper fracture because of vascular impairment and sepsis A great defect in the posterior part of the calf was covered with an extensive skin graft The 8 cm tibial stump was very sensitive to touch and two neuromata could be palpated which were adherent to the skin graft A fitting with a P T B prosthesis was tried but was unbearable to the patient because of the pains in the skin covered area over the fibula

The scar was excised the fibula and the peroneal nerve and neuroma were resected The skin could be closed without difficulty The patient was fitted with a P T B prosthesis and has no difficulty in walking

4 T B Below knee amputation because of vascular impairment after open fracture of right leg in 1962 He walked poorly with a conventional prosthesis with a thigh corset because of pain in the stump and over the fibula In 1969 he suffered a fracture of the patella of the same leg The patella was excised A prosthetic fitting was unsuccessful The stump was 10 cm long the tibia covered by tender skin the fibula protruding and the extension of the knee was incomplete The triceps muscle was not attached to the bone

After fibulectomy resection of peroneal nerve attachment of the triceps to the bone the patient was very satisfactorily fitted with a P T B prosthesis

In exceptional situations even the hamstrings may be severed in order to gain additional length of the stump We have tried this step as well but have not had enough experience in order to express an opinion

DISCUSSION

The static and dynamic alignment of the prosthesis for a short tibia stump is dictated by the forces acting upon the stump These forces have been extensively studied by Radcliff (1970) and we follow his description

There are two kinds of forces in action

1 The body weight acts through the gravity line
2 The floor reaction forces act upon the stump through its socket in vertical and lateral directions

In mid stance position in the frontal plane, the floor reaction has a medial oblique and upward thrust causing a lateral inertia force The horizontal component of this oblique force acting in medial direction generates an inertia force which is opposed to it

If we assume the point of application of all vertical forces on the stump as a balance point—at equilibrium—the inertia effect plus the lateral force must be equal to the body weight

In other words equilibrium must be created between the body weight and the distribution of all the forces acting upon the stump

In a short stump the lateral force acts on a small weight bearing surface In order to decrease its effect the foot must be laterally placed thus increasing the resulting inertia force At the same time it results in an upward displacement of the lateral stabilizing force into the sensible region of the head of fibula

In a sagittal plane at heel strike the floor reaction force acts in front of the knee causing an extension of the joint This tendency is controlled by the action of the hamstrings Special attention must be paid in construction of the socket in order to free the tendons of these muscles In the following phases of foot contact the reaction force passes behind the knee determining flexion in the joint This tendency is resisted by the quadriceps pull In this plane the forces between stump and socket act on three areas patellar tendon area the end of tibia and the popliteal region It follows that in the short stump the posterior brim of the socket must be high to ensure a larger surface of contact and to limit the extent of flexion

After excision of the head of the fibula, other weight bearing areas are presented The small lateral area in front of the fibula is now a similar weight bearing area as on the medial site The only difference in these two areas is that the lateral area begins below the tibial crest which is quite prominent while the medial area starts 1 1½ cm more proximally and is more sloping Together with the area of the ligamentum patellae three well defined areas for weight bearing are presented in front of the stump In the popliteal region the socket must reach as high as possible in order to prevent the bearer of the prosthesis from flexing the knee over 70–80 This precaution ensures the fit in flexion and prevents the stump from slipping The posterior borders are well defined in the plaster of paris positive (Figures 1 c 2 c 2 d)

The importance of a functioning knee joint and the preservation of even a short below knee stump are evident The proprioceptive sensation transmitted through the stump is very important for good walking Even if the forward thrust of the short tibia lever is limited the below knee stump is to be preferred to amputation at a higher level

A tibia stump shorter than 7½–8¾ cm in length is our main concern here This stump is painful with pressure areas over the head of fibula and most parts of the tibia Such a stump rubs inside the socket and tends to slip out and in There is a need to grasp such a stump more securely inside the socket and to prevent excessive points of pressure If one takes into account the insertion of the hamstring muscles in the back of the knee the difficulties for a snug fitting are even greater It seems to us that the term short stump is more an expression of stability and fit of a stump than of its length

The excision of the fibula and the resection of the nervus peroneus have in our hands given us the chance to solve this very difficult problem as was reported by Erlacher (1917) Horworth (1952) Kirk (1963) Thomsen (1967, Alldredge & Murphy (1968) Murdoch (1970) and Loon (1970) In many of these patients we could improve the quality of the skin scars by adequate excision of skin available after fibulectomy

The fitting of a prosthesis after this procedure did not cause any difficulties We never observed rotation of the socket around such a stump as was mentioned by Gillis (1954) Mercer & Duthie (1967) and Dederich (1970) as reason for opposing the excision of the fibula All our patients are men and we have had no experience with such a stump in women where a badly configurated knee could cause problems for fitting

All these patients have been fitted before this procedure with different types of prostheses even with conventional ones and several were fitted abroad before we proceeded with our plan This therefore presents a solution for short below knee stumps if a previous trial fitting was unsuccessful

SUMMARY

1 The term "short tibia stump" is characterized by length and form of the stump

2 These stumps present fitting problems because of the insufficient areas for weight bearing and the protrusion of the head of fibula

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RIDING ACCIDENTS

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Little is known about the nature or incidence of riding injuries The literature contains only a few case reports and no data on the incidence of accidents Injuries among horse soldiers have received more atten tion and Breitner (1953) refers to several authors Eastwood (1969) studied the incidence of injuries in different kinds of sports including polo

Riding as an outdoor pastime is becoming increasingly popular and we therefore thought it worthwhile to try to survey the types and the incidence of riding accidents

MATERIAL

In the city of Malmo there are three riding schools with altogether 1 908 members These schools have 45 horses and 11 ponies besides which many members have their own horses

In a prospective one year study (1970–1971) a special register was kept of all patients admitted as emergency cases because of riding accidents

Since Malmo General Hospital is the only hospital in the city for acute illness all persons requiring immediate treatment because of injury and therefore all persons requiring treatment because of riding injuries are referred there

The material consisted of 119 patients 24 males and 95 females The age distri bution is given in Figure 1 The average age was 18±1 0 years (25±3 1 for males and 16±0 9 for females)

The sex and age distribution is probably representative of only the population at risk.

Incidence of injuries

During the period in question the members had received in all 38 100 riding lessons (hours of instruction) The incidence of injuries was calculated as less than one injury per 1 000 lessons.

It was not possible to assess the total incidence of riding injuries in the area covered by the hospital.

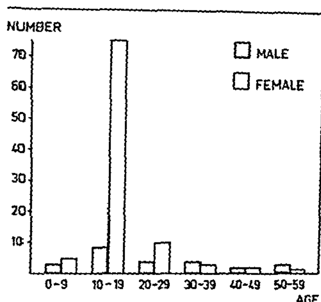


Figure 1 Sex and age distribution of injuries

AETIOLOGY

Traumatic injuries were seen in 117 cases and tendinitis in 2 The 117 injuries were caused by biting trampling kicking etc and by falls from the horse s back (Table 1)

Table 1 Distribution of injuries according to cause

Accidents occurred while rider was	Number of injuries	Bite	Trampling	Kick	Compression	Fall
grooming the horse	12	5	2	5	–	–
leading the horse	12	–	8	3	1	–
holding the horse	4	2	2	–	–	–
riding	93 (7)	2	4	7	1	79
not specified	3	1	1	1	–	–
Total	124 (7)	10	17	16	2	79

Figures in brackets denote number of combined injuries.

Biting Horse bites had caused small bruises and scratches of the skin but in only one case did the injury require excision and suturing The injuries were localised to the hand and forearm (5 cases) thigh (3 cases) nose and mamilla

Trampling injuries The injuries were mild contusions (11 cases) sores (1 case) and fractures of the wrists and toes

In 3 cases the injuries were more severe *viz* cerebral contusion facial injury and fracture of the navicular bone open comminuted distal intra articular fracture of the lower leg and hand injury with finger fractures These injuries were seen in experienced riders who had continued to hold the reins after they had fallen from the horse s back

Kicks In 4 cases the rider had been kicked by another horse while he was on a horse s back in 12 cases while he was standing on the ground In the former group it was always a lower limb that had been kicked Several serious *injuries due to kicking occurred viz* concussion of the brain in 2 cases subcapsular liver rupture fractures of the mandible lower leg radius and finger injuries requiring suturing in 5 cases and contusions in 4 In 3 cases the rider was kicked while he was leading a horse with long reins and happened to come behind the horse in one case the rider continued to hold the reins after having fallen from the horse

Compression injuries In 2 cases the rider had been compressed between the horse and the wall (finger fracture contusion)

Tendinitis Gripping of the reins had caused tendinitis in two cases one of type Mb Quervain and the other of the flexors of digits 4 and 5

Injuries due to fall from horse Of all the injuries two thirds were due to falls from a horse s back The types of injuries were the same whether the *rider had fallen from the back of a horse or a pony* Fifty two of the accidents occurred outdoors and twenty two indoors The former appeared to be more serious than the latter Of the 8 cases of concussion of the brain 7 occurred outdoors

The most common reason for the fall was the horse s jumping aside or bucking Most of the accidents (48 out of 79) occurred during a gallop only 6 during a jump and 3 during a race

Falls were commonest among those members who had their own horse or pony and were not receiving lessons (Figure 2)

The sites and types of injury are given in Table 2

No skull fracture was demonstrable in any of the 8 cases of cerebral concussion Of the 79 riders who fell 55 were wearing a helmet (and 24 were not) Cerebral concussion was equally common whether the riders were wearing a helmet or not (The difference was *not significant*) Two of those wearing a helmet lost it during the fall

The injuries were mainly of the upper limbs and then consisted

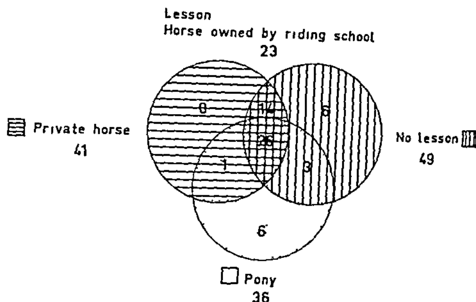


Figure 2 Injuries due to fall from horse or pony owned by riding school or rider during or not during a lesson (79 accidents)

mainly of fractures caused by indirect violence when falling on the extended arm

Of the 119 persons injured one third could ride again within a week after the accident two thirds within a month and all except one within 6 months

COMMENTS

The risk of accidents during riding is not greater than that in most other sports The incidence of injuries during riding lessons is less than one per thousand lessons which is not more than that for swimming and long distance skiing (Table 3)

Accidents are probably more common during outdoor riding than indoor riding and they are generally more serious

Traumatic injuries from the horse (biting trampling kicking and compression) or during a fall from the horse s back are the most common types Typical riding injuries are fractures at various levels of the upper limbs owing to indirect violence when the rider falls from the horse s back onto his hands

Serious injuries are fairly uncommon They usually occur when the

rider after having fallen from a horse's back continues to hold the reins and is then trampled or kicked by the horse or when the rider is leading a horse with long reins and happens to come behind the horse

Table 2 Injuries in 79 cases due to fall from horse

Head	Cerebral concussion	8
	Soft tissue injury	1
	Sum	9
Trunk	Rib fracture	2
	Vertebral fracture	7
	Pelvic fracture	1
	Contusion	7
	Sum	17
Arms	Collar bone fracture	3
	Upper arm fracture (neck of humerus)	9
	Elbow fracture or dislocation	4
	Forearm fracture (diaphysis)	9
	Forearm fracture (distal)	2
	Metacarpal fracture	2
	Contusion sprain	19
	Sum	48
Legs	Femoral fracture	2
	Lower leg fracture	2
	Ankle joint fracture	2
	Contusion sprain soft tissue injury	12
	Sum	18
	Total	92

When a rider falls from a horse he should not hang on to the reins When walking beside a horse he should not lead it with long reins

The frequency of skull injury was not high despite the risk of hitting the head when falling from a horse's back especially outdoors The use of a helmet ought to be a good precaution but remarkably enough as many as one out of every three riders do not use one On the other hand it might be questioned whether the conventional helmet with a rubber chin strap does not fall off far too easily

Table 3 Incidence of injuries in different sports

	Eastwood 1969 Accidents/10^3 exposures	Howorth 196? Accidents/10^3 man days	Apelqvist 1962 Accidents % insured and year
Rugby	87 9	[illegible]	
Football	6 1	9	8 9
Basket ball	2 5	1 3	
Hand ball	1 6		6 3
Volley ball	0 1		
Tennis	0 1		
Ice hockey	2 5	7	5 6
Bandy			4 1
Downhill skiing		6	
Long distance skiing	1 0		
Wrestling	10 7		
Boxing	4 6		
Fencing	1 3		
Polo	11 2		
Swimming	0 6		

SUMMARY

In a 1 year prospective investigation 119 patients with riding injuries were seen at the Malmo General Hospital

The incidence of injury during riding lessons was less than 1 per one thousand lessons

Accidents were most common among those who had their own horse or pony and were not receiving lessons Outdoor injuries were more serious than those sustained indoors

One third of the injuries were due to biting trampling kicking and compression and two thirds to falls from the horse

Typical riding sport injuries are fractures at different levels of the upper limbs produced by indirect violence when falling from the horse

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DNA SYNTHESIS IN DEGENERATED AND NORMAL JOINT CARTILAGE IN FULL-GROWN RABBITS

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It is known that joint cartilage in young growing animals grows by mitosis (Elliott 1936 Mankin 1962 a 1963 a 1963 b 1964 and 1968) However once the animal is full grown such mitotic growth appears to cease for mitoses have never been demonstrated in normal joint cartilage in adult human beings or animals (Elliott 1936 Clark & Clark 1942 Crelin 1957 Crelin & Southwick 1960 Mankin 1963 a 1963 b 1964, 1968 Hulth et al 1972 Telhag 1972) It has been shown that joint cartilage can react to trauma with cellular proliferation (Crelin 1957 Crelin & Southwick 1960 Mankin 1962 b Telhag 1972) and increased synthesis of glycosaminoglycans in the matrix (Collins & McElligott 1960 Bollet & Nance 1966 Bollet 1969 Mankin & Lippiello 1970 Telhag 1973) Crelin (1957) and Crelin & Southwick (1960) demonstrated that experimental compression of the knee joints in full-grown rabbits is followed by rapid progressive degeneration of the joint cartilage With the aid of intraperitoneal injection of colchicine single mitosis of chondrocytes was demonstrated in the degenerated cartilage but no mitoses were found in the normal joint cartilage

The present investigation was undertaken to find out

1 Whether cartilage cells in degenerative joint disease can be labelled with ³H thymidine
2 whether ³H thymidine can be taken up by normal cartilage cells in full grown rabbits
3 whether ³H thymidine can be taken up by cartilage cells after sham operations and

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4 whether ^{3}H thymidine can be taken up by cartilage cells in old rabbits

MATERIAL AND METHODS

Forty two full grown rabbits were used

Experiment 1

Twenty two rabbits were operated upon in one of the knee joints according to a method described by Hulth et al. (1970) to produce degenerative changes in the joint A piece of the medial collateral ligament was excised the medial meniscus was extirpated and the anterior and posterior cruciate ligaments were divided The other knee served as a control

The animals were killed 2 at a time by intravenous injection of Nembutal in a lethal dose 1 3 5 7 10 15 days and 1 2 3 4 5 months respectively after the operation *Four hours before the animals were killed 20 μCi ^{3}H thymidine (from the Radiochemical Centre Amersham aqueous solution containing 5000 μCi/mM)* in 0 2 ml physiological saline was injected into each knee joint

Both knees were removed and fixed in 10 per cent formalin The tibial and the femoral ends of the joints were dissected free and treated separately Both the tibial and the femoral parts were afterwards divided in the frontal plane into two halves with a saw The 4 halves were decalcified in formic acid and afterwards embedded in paraffin The preparations were sectioned (7 μ) Autoradiograms of routine histological preparations were made with Ilford K2 liquid emulsion After exposure for 2 and 3 weeks respectively the autoradiograms were developed in Gevaert X ray developer G 230 and fixed in Gevaert X ray fixer G 305 The sections were stained through the emulsion with Mayers haematoxylin Two to 5 auto radiograms of the tibia and the femur respectively of each knee joint of each animal were examined

Experiment 2

Twenty μCi ^{3}H thymidine in 0 2 ml physiological saline was injected intraarticularly *into each knee of 3 full grown rabbits The injection was repeated every sixth* hour for 2 days i e each knee received altogether 8 injections Six hours after the last injection the animals were killed Both knee joints were removed and treated in the same way as in Experiment 1 Sections were cut at various levels of each preparation for histological examination and for autoradiography A few preparations of unsatisfactory quality were discarded

Altogether more than 500 sections of the tibia femur and patella were obtained for autoradiographic examination

Experiment 3

Ten full grown rabbits were operated upon with arthrotomy via a medial para patellar incision The unoperated knee joint served as a control When the joint was opened care was taken that the capsule bled into the joint if necessary by a small incision in the capsule. The joint was then closed The animals were killed

2 at a time 3 5 10 15 and 30 days after the operation Four hours before the animals were killed by a lethal dose of Nembutal i v 20 μCi ³H thymidine in 0 2 ml physiological saline was injected into each knee joint Both knee joints were removed and treated in the way described in Experiment 1 Sections for histological and for autoradiographic examinations were cut at various levels of each part of the tibia and femur More than 450 autoradiograms were examined Some preparations of unsatisfactory quality were discarded

Experiment 4

Seven rabbits more than 4 years old including 2 more than 5 years received an intraarticular injection of 20 μCi ³H thymidine in 0 ? ml physiological saline in both knee joints Four hours later the animals were killed with an overdose of Nembutal i v The tibial and femoral ends of the joint were removed and treated in the way described above after which sections were cut for histological as well as for autoradiographic evaluation At least 5 autoradiograms from each part of the tibia and 5 from each part of the femur i e in all about 320 were examined.

RESULTS

Experiment 1

The cartilage of one of the *unoperated knee* joints was found to contain several thymidine labelled chondrocytes in the superficial and transitional layers in the medial tibial condyle Cellular death was suspected in the superficial layer and possibly also in the transitional layer and in some of the preparations also flaking of the superficial layer No thymidine labelled chondrocytes were found in preparations from the remaining 21 unoperated knee joints

In the *operated knees* thymidine labelled chondrocytes were found in animals examined 5 days to 5 months after the operation Such cells were found in all the animals except 3 the latter examined 5 7 and 150 days respectively after the operation In the preparations studied 5 7 and 10 days after the operation the labelled cartilage cells were situated mainly in the superficial and transitional layers near the medial or lateral margins and near the attachments of the anterior and posterior cruciate ligaments In preparations removed 15 days and 1 month after the operation the labelled chondrocytes were scattered more and more evenly over the entire surface of the joint cartilage and more and more often in the columnar layer These preparations also showed clones containing labelled cartilage cells usually in the superficial layer but also in the transitional and the columnar layers As a rule these clones contained only one labelled nucleus occasionally 2 or more In the preparations obtained 2 3 4 and 5 months after the

operations labelled cartilage cells were more common in the transitional and columnar layers and occasionally such cells were found near the border of the calcified layer In the 3 month sections occasional clones with labelled cartilage cells were seen near the calcification line

Experiment 2

The histological sections showed no signs of degenerative changes of the cartilage Only one knee joint showed some labelled cartilage cells

Experiment 3

The histological preparations showed no degenerative changes in the cartilage In 3 knee joints examined 5 10 and 30 days after arthrotomy cellular proliferation was seen in the margins near the periosteum The above mentioned 10 and 30 day preparations showed also a moderate osteoblast activity subperiostally in the margins No labelled cartilage cells were found in the autoradiograms

Experiment 4

In one animal both knees showed signs of degenerative changes (the cartilage with clones flaking and fibrillation Cartilage cells w occasionally seen in the superficial and transitional layers Re maining preparations showed no degenerative changes with cert and no labelled chondrocytes

DISCUSSION

Joint cartilage was formerly regarded as an inert tissue an in cartilage in full grown animals was considered rare Res the last 10–20 years has however shown that adult joint react to trauma with cellular proliferation (Crelin 1957 (wick 1960 Mankin 1962 b Telhag 1972) and an increas glycosaminoglycans (Collins & McElligott 1960 Bollet & Bollet 1969 Mankin & Lippiello 1970 Telhag 1971) in degenerative joint disease also the synthesis of colla (Repo & Mitchell 1971) Although Pelc (1964 1968) some cells in non dividing tissues for example metabolic DNA which has nothing to do with cel

be assumed (Hughes 1959) that DNA synthesis occurs mainly in association with cellular proliferation The purpose of the present investigation was to find out whether the production of degenerative changes of the cartilage in the knee joint in full grown rabbits by surgically induced instability of the joint results in an increased number of labelled cells in the joint cartilage This possibility was confirmed in the present investigation which showed labelled cartilage cells in the operated knee of 19 of 22 animals As early as 5 days after the operation thymidine labelled cartilage cells were demonstrated while histological degenerative changes of the cartilage did not appear until 15–30 days after the operation Labelled cartilage cells were also demonstrated in those groups of cells (clones) which are typical of osteoarthritis which suggests that such clones may be the result of mitosis These findings agree with those found *in vitro* in human joint cartilage (Hulth et al 1972)

Control examinations confirm that in full grown rabbits ³H thymidine labels a larger number of cells in cartilage degenerated by instability of the knee joint than in normal cartilage Such labelling was found in the unoperated side in only one of 22 knees It cannot be excluded *a priori* that mitosis may occur in normal adult cartilage but if so the G_1 phase is so long that it cannot be demonstrated by ordinary flash labelling ³H thymidine was therefore given 8 times within 2 days in both knees of 3 full grown rabbits In only one of the 6 knee joints could any labelled chondrocytes be demonstrated In addition knee joints of old rabbits (more than 4 years) were examined for spontaneous mitosis In only one of the 7 knee joints studied could such spontaneous labelling be demonstrated and in that knee the joint cartilage was degenerated

Another question is whether the operative trauma *per se* can cause a reaction of the joint cartilage Sham operations consisting of arthrotomy and induced bleeding into the joint were performed on 10 rabbits In none of them could labelling with ³H thymidine be demonstrated The degenerative disease of cartilage produced by instability of the knee joint resembles spontaneous osteoarthritis in some respects The histological changes show the same pattern (Collins 1949) Earlier investigations (Mankin & Lippiello 1970 Telhag & Gudmundson 1972) have shown that the DNA synthesis is increased in degenerative joint disease in man and in animals This has been confirmed in the present investigation The experimental model used produces degenerative osteoarthritic like joint disease Attempts to repair degenerative

changes in the matrix may be considered typical of osteoarthritis As shown in the present investigation this attempt to repair is associated with an increased number of cells labelled with ^{3}H thymidine, which may suggest mitoses a phenomenon hardly ever seen in normal full grown rabbits

SUMMARY

Chondrocytes in the joint cartilage in full grown rabbits with degenerative changes of the cartilage can be labelled with ^{3}H thymidine Sham operations do not produce degeneration of the cartilage or result in the labelling of cartilage cells In old animals primary osteoarthritis with cartilage cells capable of taking up the label may perhaps develop Division of cartilage cells occurs only rarely if ever in adults

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THE ROLE OF PETAL TECHNIQUE IN ACTIVATION OF OSTEOGENESIS

An experimental study

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During the last six years the standard treatment of delayed and non union of fractures of long bones at the SMS Medical College Hospital Jaipur has been the use of the petal technique combined with modified Phemister s bone grafting procedure Clinical observations suggested that by addition of this technique the union was quicker and the callus radiologically appeared more abundant and structurally superior The results were so impressive that it was decided to carry out an experimental study to evaluate the efficacy of petal technique under controlled conditions The term petal describes a piece of bone elevated from the cortex in such a manner as to leave its base attached to the parent bone (Figure 1)

MATERIAL AND METHODS

This study was carried out in 23 albino rats male and female weighing 100–150 g. During the period of study one limb was used as the test limb with the other limb serving as control in the same animal Intraperitoneal sodium pentobarbital 3 mg 100 g body weight was used for anesthesia.

On the control side anteromedial and anterolateral surfaces of tibia were exposed and near the tibial prominence a hole was drilled through the cortex into the medullary canal of the tibia The bone was divided transversely distal to the tibial spine with a knife blade A stainless steel pin was pushed through the drilled hole into the tibia across the fracture site to achieve immobilization Comminution at the fracture site was always avoided and if it occurred the rat was discarded from the experimental series On the test side 6–8 petals were raised proximal and distal to the fracture site on the lateral and medial surfaces before causing the fracture with a knife

All the animals were subjected to the same controlled diet and environmental conditions They were divided into four groups and were sacrificed 12 20 30 and

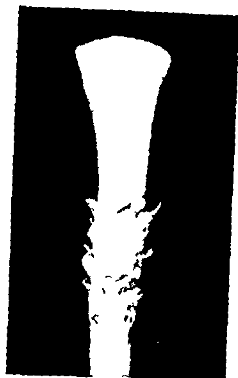


Figure 1 Plaster of Paris model of tibia showing petals raised from original cortex

40 days postoperatively i e Group 1 (12 days) Group 2 (20 days) Group 3 (30 days) and Group 4 (40 days)

The tibiae were dissected out and under fairly strict control of radiological constants X rays were taken Density volume of callus and periosteal reaction proximal and distal to the fracture site were closely observed Resorption of cortex near the fracture line was also noted After X rays the intramedullary pin was removed and tensile strength (breaking load) was measured. It was designed to find out the weight necessary to break the union at the fracture site under carefully controlled conditions as described by Jarry & Uhthoff (1960) Weights were added in increments of 50 g until the fracture recurred Histological studies were undertaken on the specimens ½ cm proximal and distal to the fracture site Haematoxylin and Eosin staining techniques were used for regular studies and for collagen tissue Van Gieson staining technique was used Longitudinal sections showing callus across the fracture site could not be obtained because all the tibiae were subjected to tensile strength test

OBSERVATIONS

Radiological

The control side in Group 1 (12 days) showed relatively less callus with some cortical thinning The test side showed more callus and its continuity was more marked The cortical thinning near the fracture

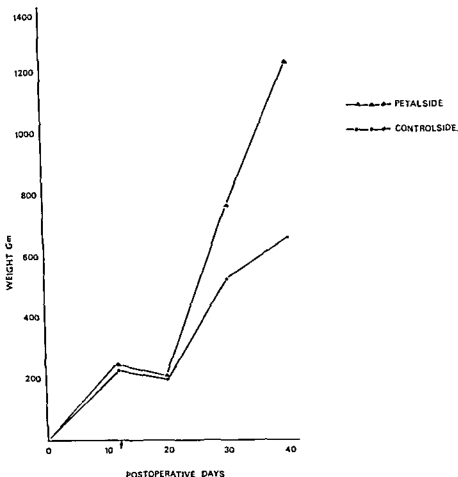


Figure 2 Shows mean values of weights required for breaking the bone near the fracture site on the petal and control sides Note the drop in strength in Group 2 and sharp rise in strength in Groups 3 and 4

site was more pronounced The density of callus on the two sides and the periosteal reaction showed no significant difference In Group 2 (20 days) when compared to the control side the fracture gap on the test side was less visible and the callus appeared to be denser and more compact Cortical thinning at the fracture site and the periosteal reaction were also more pronounced

Group 3 (30 days) The test side showed only a faintly visible fracture gap much less than the control side and the callus appeared

to be denser and better fixed to the cortex Again definite superiority of union on the test side was noticed in Group 4 (40 days) The fracture line was barely visible on the test side A good amount of dense callus well fixed to the cortex was seen in all the cases There was also evidence of remodeling of shape

Tensile strength test

The mean of weights required to break tibiae in Group 1 on the control side was 239 g as compared to 249 g on the test side In Group 2 there was no significant difference in their absolute and mean values In fact these values were lower than the ones in the previous group control/test 201 211 At 30 days in Group 3 a difference of 243 g in mean values was noticed in favor of test side 773 g compared to control 530 g A 90 per cent increase in tensile strength on the test side as compared to the control was evident in Group 4—Test/control 1237 660 —mean difference of 577 g (Figure 2)

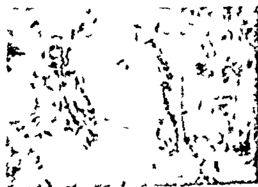


Figure 3 Shows base of petal attached to original cortex petal is surrounded by newly forming callus suggesting its osteogenetic potential



Figure 4 (Group 2 control side) Showing periosteum and fibrocartilaginous callus Scanty osseous tissue

Figure 5 (Group 2 petal side) – Compared from Figure 4 Abundant osseous callus with mature fibroblasts



Histological

Group 1 The control side showed a moderate amount of callus The striking feature was the high cellularity with plump and immature fibroblasts Many islands of cartilaginous matrix were seen with very little osseous tissue The callus was poorly anchored to the original cortex with little evidence of cortical activity Collagen tissue was scanty On the test side callus was abundant and better fixed to the cortex The fibroblasts appeared more mature Although there were islands of cartilaginous matrix osseous tissue was increased compared to the control side In a few slides petals could be easily identified by their density identical to the original cortex and the direction of their fibers some petals were also seen surrounded by callus suggesting osteogenetic potential (Figure 3)

Group 2 Poorly fixed callus with loose packed immature fibroblasts was seen on the control side and cartilaginous islands dominated the picture with only small areas of osseous tissue On the test side the callus was abundant and firmly fixed to the cortex There was evidence of cortical resorption and revascularization Most of the cells were mature fibroblasts and the osseous matrix dominated the picture (Figures 4 and 5)

Group 3 The control side still showed many islands of cartilaginous matrix immature fibroblasts and few patches of osseous tissue On the test side more maturation of osseous matrix and areas of calcification were noticed Cartilaginous tissue was sparse Collagen was more prolific than on the control side (Figures 6 and 7)



Figure 6 (Group 3 control side) – Fibrocartilagenous callus Small osseous islands

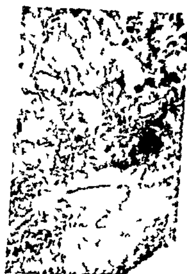


Figure 7 (Group 3 petal side) – Mature osseous callus with moderate cellularity Some areas of bone minerali ation

Group 4 Some increase in the bulk of collagen tissue and improvement in the fixation of callus to the original cortex was seen on the control side but there was still a predominance of cartilaginous tissue The test side showed a significant increase in osseous matrix and calcified zones Some cartilaginous islands in the transitional phase to mineralization with poor cellularity were noticeable Collagen tissue was adequate on the test side as compared to the control

DISCUSSION

To study the comparative results of a treatment in relation to fracture union it is essential that as far as possible there be no extraneous factors which may affect the process of fracture healing This ideal is difficult if not impossible to achieve in clinical practice In the

Table 1 Statistical evaluation of stability test

...ys	Group	No of animals	Mean difference	Standard error of mean difference	90 % confidence interval for μ the true mean difference	95 % confidence interval for μ the true mean difference
	1	5	10	17 88	$\mu <$	
	2	6	10	37 14	$\mu <$	
	3	5	243	30 892	$\mu > 194$	$\mu > 178$
	4	6	577	83 66	$\mu > 442$	$\mu > 418$

Column 4 indicates the mean difference in breaking strength of the two sides
Column 6 gives lower bound for the true mean difference which in 90 % of the cases will be exceeded

Last column gives for animals sacrified after 30 and 40 days a lower bound of 178 g and 418 g as the true mean difference between the two sides in favor of petal technique with a probability of 95 %

experimental laboratory this problem can be reduced to two variables (1) fracture healing in normal course and (2) fracture healing with the addition of the petal technique In the present study an attempt was made to keep all other factors constant by producing identical fractures at the identical site by an identical method A clean division with a knife was preferred as force used to produce fracture manually could not be adequately controlled Hormonal factors influencing osteogenesis were cancelled out by using both male and female animals Petal technique was used alternately on the right and left side thus each animal served as its own control Immobilization of fracture site was achieved by using stainless steel intramedullary pins applied similarly to the control and test side The healing process continued under identical physical nutritional and hormonal influences

In the present study the quality of callus was decided by (1) radiologic evidence (2) histologic evidence and (3) tensile strength resulting from healing of fracture as a function of time All the above parameters were found favorable on the petal side in all the cases Bourne (1944) has shown that overproduction of callus is often in inverse proportion to its quality In the present study the quality of the abundant callus on the test side was found superior radiologically mechanically and histologically

The *radiologic findings* were in accordance with the findings reported by Jarry & Uhthoff (1960) the decalcification and revitalization

of cortex was always more pronounced on the petal side The callus on the petal side was superior in quality *depending upon its volume* density adherence to the cortex and appearance of fracture gap

Anatomically, healing of fracture may be observed by radiographic or *histological examination but neither of those two* methods measures the functional state of fracture site The tensile strength test was undertaken to assess the mechanical strength of callus at the fracture site Weights required to break the test and control side were almost identical and the mean difference had no significant value in Group 1 The overall inferiority of mechanical strength of the callus in Group 2 over that of Group 1 can be attributed to the shrinkage of callus revascularization and thinning of the cortex This observation is supported by the findings of McKeown et al (1932) who reported a sharp loss of strength between 15-21 days by 40 per cent possibly attributing it to some chemical factor responsible for destroying the units of calcified mass Definite evidence of difference in strength was observed in Groups 3 and 4 At 30 days there was a mean difference of 243 g in favor of the test side At 40 days there was 90 per cent superiority on *the test side (1237 g) over that of the control side (660 g)* In no instance did the bone break at a site other than the fracture site suggesting that the fusion had not occurred completely

According to clinical observations *oblique and comminuted fractures* lead less often to nonunion than transverse fractures Cretin (1940) explained this on the grounds of an increase in contact area of fracture site with the surrounding soft tissues He also suggested *that the in*creased surface area of fracture influenced osteogenesis favorably by (1) throwing into action a larger number of osteogenetic cells (2) by providing a larger area for anchorage of callus and (3) by facilitating revascularization In petal technique the term petal describes a piece of bone elevated from the cortex in such a manner as to leave its base attached to the parent bone The technique provides (1) increase in surface area of fracture and an increase in the contact area with the surrounding soft tissue (2) wider and better anchorage of callus and (3) more rapid decalcification and revitalization of the cortex at the fracture site by reducing its thickness Petalling represents a directed trauma with a definite osteogenetic potential Harris (1957) explained that by cutting petals the thickness of the cortex is diminished thus diminishing the time when the cortex will be revascularized and reorganized into living bone By separating the cortex into thin petals a surface is provided which will be filled in by new bone and will give

a much greater area for the attachment of callus and more rapid revascularization and reorganization of these flakes

From time to time attempts have been made to induce delayed and nonunion fractures to unite by procedures in which bone graft is not required The role of bone transplants in favorably influencing osteogenesis is still obscure Conflicting views have been put forward (1) does the transplant actively participate in the process of osteo genesis or (2) does it merely act as a passive scaffolding for new bone to be laid down or (3) does it act as a ready source of calcium? These questions have been debated for a long time (Siffert 1955 Ray 1956 Burwell 1966 Urist 1953) An entirely different explanation has been put forward by Danis (1966) and Jarry & Uhthoff (1960) suggesting that the transplants act simply due to the reaction caused by the trauma of the preparation of the bed for the graft In the treatment of delayed and nonunion fractures petalling can be usefully added to Phemister bone grafting in which the osteogenetic potential of cancel lous bone graft can be combined with that of petalling leading to firm union in the area of fibrocartilaginous bridge of fracture gap and thereby avoiding the risks of fracture of donor site and the loss of corti cal graft from infection Based on the same concept McElvenny (1963) advised the use of fish scaling (similar to petal technique) in arthrodesis of the knee Prophylactically this procedure can be used during open reduction and internal fixation of fresh or old fractures of long bones to reduce the chances of delayed union which could result from intramedullary nailing and thus lessen the total period of morbidity

Addition of petalling to any of the above procedures would not increase the magnitude of operative shock or trauma It would increase the operative time insignificantly if at all This study suggests that the tensile (breaking) strength is significantly accelerated by use of this technique It is not suggested that this technique will produce end results better than the other techniques It is suggested from this study that by use of this technique patient morbidity can be decreased

SUMMARY

This paper describes a simple surgical procedure for stimulating osteogenesis by the use of petal technique This procedure is applicable in open reductions for the treatment of transverse or short oblique fractures By increasing the contact area of the fragments with the surrounding tissues by promoting anchoring process at the fracture

site and by biological changes of the compact bone acceleration of the fracture consolidation is achieved These facts have been established by radiological histological and tensile strength studies conducted in 23 rats The advantages of this method are (1) simple surgical procedure (2) it does not increase surgical trauma or shock (3) it hastens the healing process at the fracture site

The present study suggests that the use of this simple technique can significantly reduce morbidity in selected cases

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ASSESSMENT OF FRACTURE HEALING IN MAN BY SERIAL ^{87m}STRONTIUM SCINTIMETRY

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Primary bone healing after rigid osteosynthesis of fractures occurs by direct bridging of the anatomically reduced fracture line by regenerating Haversan systems (Schenk & Willenegger 1967) Provided rigidity of fixation is sufficient there is no visible callus formation on the radiograph and it can be difficult to determine when the fracture has consolidated (Wieser 1964) This process of primary bone healing is morphologically very different from that found in fractures treated by classical conservative immobilization methods

Radionuclide tracer methods for studying benign skeletal conditions in man have been widely used (Bauer & Wendeberg 1959 Wendeberg 1961 Bessler 1967 Bauer 1968 Segmuller et al 1970 Fueger et al 1971) The short lived bone seeking radionuclide ^{87m}Strontium (^{87m}Sr) is now easily available Due to its short physical half life (2 8 h) frequent repeat measurements are feasible with little radiation risk to the patient

In this study we have performed repeat quantitative ^{87m}Sr uptake measurements (scintimetry) at the fracture site over several months in the same patient in order to answer the following questions

How does radionuclide uptake vary in conservative and operative treatment of normally healing fractures of the lower leg?

Do tracer methods allow early detection of non uniting fractures?

The first radionuclide uptake studies in fractures in man were done with ^{85}Strontium (T½ 65 d) Bauer & Wendeberg (1959) demonstrated increased uptake of ^{85}Strontium (^{85}Sr) by fractures of the femur and tibia in man After a single injection of radionuclide the uptake ratio fractured intact leg increased with time They emphasized the fact that a high uptake does not necessarily mean a high rate of fracture healing as resorption of mineral might be as high as accretion

In a series of 61 patients with lower leg fractures Wendeberg (1961) performed quantitative radionuclide uptake measurements (scintimetries) after a single injection of ^{85}Sr He compared the data on different patients and showed that ^{85}Sr uptake reached a peak five to ten months after fracture and that it remained higher than on the controlateral side up to nine years after the accident He found no correlation between clinical healing and accretion rate. There was no difference in uptake between normally healing fractures and delayed or non union

Increased ^{85}Sr uptake by the reactive as well as the atrophic type of non union of the lower leg was demonstrated by Segmüller et al (1970) Bessler (1967) thought that increased ^{85}Sr uptake at the site of intertrochanteric osteotomies of the hip was a sign of delayed union

It seems difficult to judge fracture healing by a single radionuclide uptake measurement The long physical half life of ^{85}Sr (65 d) does not allow repeat measurements at intervals shorter than five to six months. This interval is too long considering the fact that the question of allowing weightbearing in lower leg fractures arises after three to five months Some authors have therefore tried to do repeat uptake measurements of the short lived radionuclide ^{87m}Sr in fractures. After daily intraperitoneal injection of ^{87m}Sr and uptake measurement at the site of lower leg fractures in rats Myers & Olejar (1963) found the increase in uptake to reach its maximum after two weeks

Fueger et al (1971) studied ^{87m}Sr uptake by lower leg fractures on serial scintigraphies in man They concluded that a locally increased uptake over the fracture was a sign of normal healing whereas diffusely increased uptake in the whole lower leg was a sign of delayed union. A persistently high uptake was considered to be a sign of non union or infection

Few authors have compared radionuclide uptake by fractures in conservative and operative treatment In the rabbit Falkenberg (1961) showed that ^{85}Sr uptake in nailed osteotomies of the radius was lower than in unnailed osteotomies Fueger et al (1971) reached the same conclusions by using ^{87m}Sr in rabbits and found the increase in uptake to last longer in unnailed than in nailed osteotomies. In man he found the ^{87m}Sr uptake in conservative treatment to be higher and to reach its maximum earlier than after stable osteosynthesis

Accurate data on ^{87m}Sr uptake by normally healing fractures based on repeat quantitative uptake measurements in the same patient are still missing The aim of this paper is therefore to establish a normal

^{85m}Sr uptake curve against time for lower leg fractures in patients treated by conservative and operative methods

MATERIAL AND METHODS

The study included 10 patients aged between 20 and 65 years. *They all had transverse*, oblique or short spiral fractures of the middle or lower third of the tibial diaphysis.

Four of the fractures were treated conservatively by axial traction using a transcalcaneal Steinmann pin for two to three weeks followed by immobilization in a long leg cast for 11 to 17 weeks. Partial weightbearing was allowed after removal of the cast full weightbearing three to five weeks later All fractures had healed within less than 23 weeks.

Stable osteosynthesis was achieved by means of an A.O.-compression plate in six *fractures. Four fractures united sufficiently to allow full weightbearing within* 12 to 20 weeks Two fractures developed non union.

For each scintimetry the patient was injected intravenously with 1 mCi ^{85m}Sr The length of both tibiae was divided into 10 equal segments. Three hours after injection, the patient was placed supine and the legs held in position by sandbags. Duplicate uptake measurements were made over each segment of both tibiae by means of a Mecaserto MO4 scintillation scanner equipped with a 3 × 3 inch NaI crystal shielded by a 37 hole focussing collimator and connected to a scaler The detector was repositioned between the two measurements The counting rates were corrected for background activity physical decay of ^{85m}Sr and absorption by plaster which had been measured to be about three per cent for an average thickness of plaster of Paris. For each segment the uptake ratio fractured intact leg was calculated. The average ratio of the five segments closest to the fracture was called *fracture uptake ratio* It is independent of the injected dose.

Scintimetries were done at 3 11 20 and 28 weeks after accident in conservative treatment and at 3 12 20 and 30 weeks after osteosynthesis in operative treatment. Absolute changes in ^{85m}Sr uptake by the fracture in consecutive scintimetries were expressed by means of the fracture uptake ratio

RESULTS

The mean fracture uptake ratios in normally healing fractures are shown separately for conservative and operative treatment in Figure 1

With *conservative treatment* uptake ratios increased over a 28-week observation period This increase was specially marked at the time of starting weightbearing (11th to 17th week)

With *osteosynthesis* uptake ratios decreased slightly over a 30 week observation period There was a slight rise in uptake at the time of starting weightbearing (12th to 20th week)

Regression analysis showed the difference in slope between the two curves to be highly significant ($P < 0.001$)

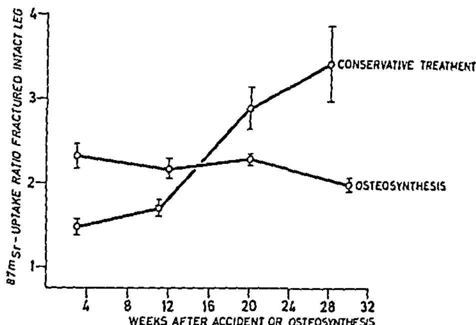


Figure 1 Average $^{8\,m}$Strontium uptal e ratios in eight normally healing fractures For each curve the data are based on measurements in four fractures The end markings represent one standar l deviation for each mean

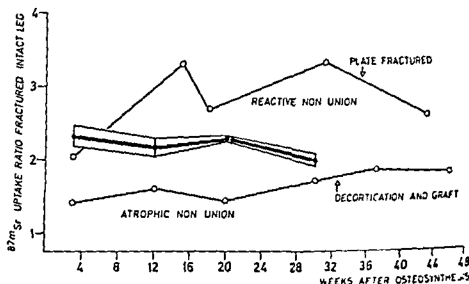


Figure 2 ^{87m}Sr uptake ratios in lower leg fractures treated l y c mpression plate The middle curve represents mean and one st in lard levi ti n f $^{8\,m}$Sr uptake ratios in four normally healing fractures 1 case f r a tir (upper curve) and ne of atrophic (lou er curve) non union shou a marked and early l parture from tl e normal uptake curv e

Two operated fractures developed non union Their uptake ratios in relation to the uptake ratios of normally healing operated fractures are shown in Figure 2 Radionuclide uptake in a case of reactive non union was abnormally high Weightbearing was allowed after 24 weeks despite clinical signs of instability and the high uptake ratios The plate broke five weeks later The uptake ratio dropped after the plate had been removed and the fracture had started to unite In a case of atrophic non union uptake ratios remained abnormally low from the start but increased slightly after decortication and cancellous bone grafting had been performed at 32 weeks

DISCUSSION

Fracture healing in conservative treatment and after stable osteosynthesis are two fundamentally different processes (Schenk & Willenegger 1967) This difference is reflected by the shape of the ^{87m}Sr uptake curves in lower leg fractures With conservative treatment callus formation and remodelling is accompanied by an increasing ^{87m}Sr incorporation into the fracture during the first 28 weeks After stable osteosynthesis direct bridging of the fracture line is reflected by a constant if not diminishing ^{87m}Sr uptake at the fracture site Increased bone remodelling after starting weightbearing is reflected in both types of treatment by a rise in ^{87m}Sr uptake

In normally healing fractures the degree of ^{87m}Sr uptake varies little from patient to patient This is demonstrated by the small standard deviation of the uptake ratios shown in Figure 1

In non union the shape of the curve as well as the uptake ratios are very different from normal (Figure 2) In a case of atrophic non union persistently low uptake was noted whereas in a case of reactive non union uptake was well above normal It is striking that these changes in ^{87m}Sr uptake appeared as early as three weeks after operation in the case of atrophic non union and 15 weeks in the case of reactive non union

Serial ^{87m}Sr scintimetry alone cannot determine the moment when weightbearing may be allowed However it seems reasonable to assume that if ^{87m}Sr uptake corresponds to the values seen in normal fracture healing weightbearing can be allowed after the usual number of weeks

Serial ^{87m}Sr scintimetry is an indication of the healing potential of fractures Marked departure from the normal values should be interpreted as incipient non union The classical treatment of non union is

decortication of the fracture region and cancellous bone grafting or osteosynthesis by a compression plate alone When clinical or radiographic suspicion of incipient non union exists it should be possible to apply this treatment earlier on the basis of serial ^{87m}Sr scintimetry than on the classical basis of clinical signs and radiographs

Serial ^{87m}Sr scintimetry thus could be developed into a useful method for cases where doubts exist as to the healing prognosis of lower leg fractures

SUMMARY

Serial quantitative ^{87m}Strontium uptake measurements (scintimetry) were performed in 10 lower leg fractures in man during the first 28 weeks after trauma Four fractures were treated conservatively and united within less than 28 weeks ^{87m}Sr uptake by these fractures rose throughout the investigation period Four other fractures were treated operatively by an A O compression plate and united within less than 20 weeks Their ^{87m}Sr uptake diminished slightly over the observation period For both methods of treatment uptake values varied little from one patient to another In two cases of non union early marked departure from the ^{87m}Sr uptake values found in normal fracture healing was noted Serial ^{87m}Sr scintimetry is therefore thought to be a method which could be developed into a useful tool for early detection of incipient non union

ACKNOWLEDGEMENT

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FRACTURE HEALING CONTROLLED BY ^{87m}Sr UPTAKE

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Fracture healing is usually supervised by clinical and radiological examinations which gives information about the stability of the fracture and callus formation In this way information is obtained about the antecedent healing but not about the active process at the time of examination The latter can be obtained by using radioisotopes which are deposited by osteoblasts in bone and which are therefore a measure of osteoblast activity at the time of the examination (Bauer 1958 Bauer & Ray 1958 McCready et al 1966 Bessler 1967 Bessler 1969)

The purpose of the present study was to measure by external counting the process of healing in a variety of fractures after intravenous injection of ^{87m}Sr to ascertain whether there was heterogeneity in the healing process and whether complications arising during healing could be detected earlier with the method described than with the usual clinical and radiological examinations

METHOD

After intravenous injection of 10 μc ^{87m}Sr/kg the radio activity was measured both over the fracture and over the symmetrical position on the normal extremity

The activity was registered continously by a point recorder for 1–1½ hours after injection Two 3 inch sodium iodide crystal scintillators were used each shielded with a cylindrical collimator (internal diameter 8 cm distance from crystal to collimator edge 10 cm) The distance from the body surface to the collimator was 5 cm To ensure consistent alignment in consecutive assays of the same patient, the position of the fracture was marked corresponding to the roentgenograms taken at the first examination

^{87m}Sr uptake was measured at intervals during the healing process. The first measurement was made as early as possible—as a rule 2 to 3 days after the initial lesion— subsequently at 1 week and later at ½ 1 2 3 and 6 month intervals.

The ratio (F N) of activity over the fracture (F) to activity over the symmetrical position in the normal extremity (N) one hour after injection was used to evaluate the material The activity was expressed directly in counts per second without

Table 1 Classification of the material by fracture type and type of healing

	Number of patients	Healing		Special cases
		Uncomplicated	Complicated	
Fractura colli femoris	5	4	1 pt caput necrosis with total collapse of caput femoris	
Fractura corporis femoris	9	6	1 pt abscess in cicatrix after osteosynthesis	1 pt op for pseudo arthrosis (checked from time of operation) 1 pt osteitis in femur (checked day 480 to day 840 after trauma)
Fractura genus	5	5		
Fractura *cruris complicata*	7	4	1 pt pseudoarthrosis Fracture consistently unstable, without callus formation 2 ptt Infection in cicatrix after osteosynthesis (one received skin transplantation in the area at a later date)	
Fractura cruris	7	3	1 pt *thrombophlebitis* 1 pt infection in cicatrix after osteosynthesis 1 pt delayed healing (clinically healed day 435)	1 pt *bilateral fractures* of crura
Fractura *malleoli*	3	2		1 pt osteitis tali (checked day 216 to day 474 after trauma)
Fractura antebrachii	3	3		
Total	39	27	8	4

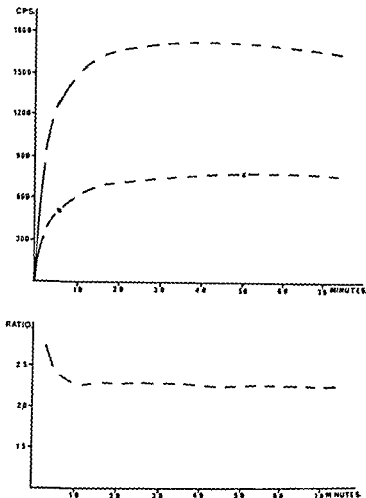


Figure 1 Top *Activity over fracture (F) and symmetrically over the opposite normal extremity (N) during the first hour after injection with* ^{87m}Sr *(Fracture — Normal × — ×)* Bottom *Ratio (F/N) of the activity over fracture and symmetrically over the opposite normal extremity during the first hour after injection with* ^{87m}Sr

correction for background which was negligible compared with the activity obtained (10^3 to 10^4 cps)

Plaster casts reduced the counts by less than 1 per cent and their effects were therefore disregarded

Some patients were injected with ^{99m}Tc labelled albumin together with the ^{87m}Sr dose As a dual channel system for each detector was not available the measuring range was alternated at short intervals between ^{99m}Tc and ^{87m}Sr energy maxima (0 142 MeV and 0.388 MeV respectively)

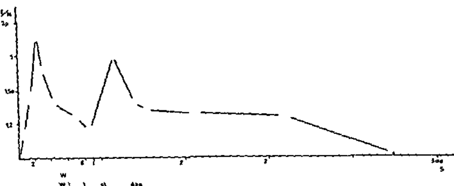


Figure 2 The ratio (F/N) of ^{87m}Sr activity over fracture and symmetrically over the opposite normal extremity 1 hour after injection during the healing period in a patient with fractura cruris

MATERIAL

39 patients (20 women and 19 men) were studied in a total of 409 assays The patients had an average age of 44 years (range 15 to ı9 years) were followed up from 38 to 570 days (average 269 days) and assayed from 6 to 16 times Classification of the material by fracture type together with some particulars of the healing process are given in Table 1

RESULTS

In all 409 assays there was an increase in activity after injection of ⁸ mSr both over the fracture and symmetrically over the normal extremity The increase was always greatest over the fracture The ratio (F/N) of the two activities either increased or decreased during the first 15 to 20 minutes after injection but subsequently became constant (Figure 1)

In all 27 patients with uncomplicated healing F/N increased during the first period following trauma and then decreased uniformly giving rise to a maximum – the initial maximum (IM) In 25 of these 27 patients a second increase and decrease was observed after weight bearing without cast immobilisation giving rise to a second maximum – the stress maximum (SM) Figure 2 shows as an example the variations in F/N during healing in a patient with fractura cruris

For the material as a whole IM occurred between day 8 and day 32 after the initial trauma or after any osteosynthesis For the individual fracture types IM occurred on average between day 18 and day 22 (Figure 3) and varied less than for the material as a whole There was

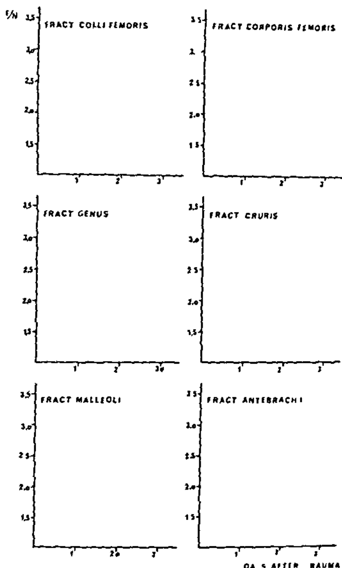


Figure 3. The ratio (F/N) of ^{87m}Sr activity over fracture and symmetrically over the opposite normal extremity 1 hour after injection at the time for initial maximum for the various fracture types in patients with uncomplicated healing

a clear tendency for IM to occur later with increasing complexity of the fracture (Figure 1)

The relatively large variation in IM values for the individual types of fracture can be seen in Figure 3. There was no relationship between IM values and the complexity of the fracture. On the other hand the

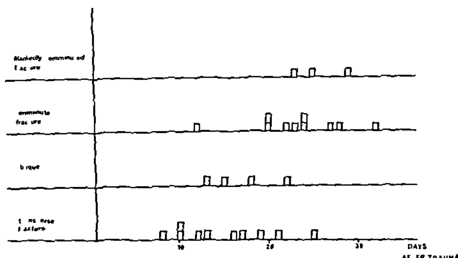


Figure 4 Histograms of time for initial maximum for fractures grouped according to complexity

average values of IM for the individual fracture types were higher the more distal the location of the fracture (Table 2)

SM occurred between day 5 and day 45 after weightbearing without plaster bandage (this rather large variation is partly due to the fact that patients at this often late stage of healing are only examined at one two or even three month intervals) and the variation in SM time was considerably less for the individual types of fracture than for the material as a whole (Figure 5) No relationship was found between SM time and the time at which the patient was ambulant without weight bearing on the fracture—with either Thomas Splint elbow crutches perambulator or with the limb in plaster neither were there any other maxima synchronous with these events

As was the case with IM SM values varied considerably for the individual types of fracture and the average values of SM were higher the more distal the location of the fracture (Table 2)

Twenty five patients with uncomplicated healing were followed up after the fractures were healed clinically The majority were followed for 60 to 180 days—a few even longer Figure 6 shows F/N at the final check in relation to time after the fractures were healed clinically

Complications in fracture healing occurred in 8 patients (Table 1) Large increases in activity over the fracture zone occurred in conjunction with infections in osteosynthetic cicatrices thrombophlebitis and

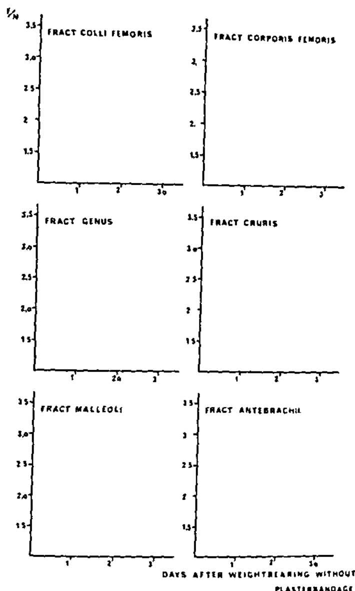


Figure 5 The ratio (I/N) of 87mSr activity over fracture and symmetrically over the opposite normal extremity 1 hour after injection at the time for stress maximum for the various fracture types with uncomplicated healing

after skin transplantation Only in one patient who developed caput necrosis after fractura colli femoris was no initial maximum found Apart from these cases the same relationships were found for patients with complicated healing as for patients with uncomplicated healing

Four patients were regarded as special cases One patient who was

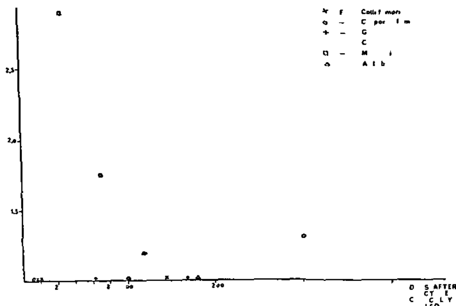


Figure 6 The ratio (F/N) of 87mSr activity over fracture and symmetrically over the opposite normal extremity 1 hour after injection at different times after the fracture clinically was healed

operated for pseudoarthrosis and supervised from the time of operation exhibited the typical curve (F/N versus time) of a new trauma Similarly one patient with a medial fracture in one leg and a distal fracture in the other leg exhibited the typical curve with distinct maxima although the values of the maxima were lower than those of patients with fractures on one side only Finally two patients with

Table 2 Average values for initial maximum and stress maximum for the various fracture types in patients with uncomplicated healing

	Initial maximum	Stress maximum
Fractura colli femoris	1.65	1.45
corporis femoris	1.90	1.95
genus	2.35	1.60
cruris	2.60	2.30
malleoli	2.65	2.45
antebrachii	2.00	2.15

respectively osteitis femoris and osteitis tibiæ arising from fractures had uniformly decreasing values of F/N at the same time as radiologically increasing sclerosis of the bones

In addition to the increases in F/N described increases of unknown origin were observed at various times in five patients with uncomplicated healing

Nine patients in 14 assays were injected with 1 mc ^{99m}Tc labelled albumin together with the ^{85m}Sr dose The curves of the activities F and N and the ratios for the two compounds during the first hour after injection were displaced relative to each other but were otherwise parallel When patients were checked several times changes in the ratios for the two compounds were closely related

DISCUSSION

A considerable haemorrhage usually occurs about the broken surfaces of a fracture The haematoma is rapidly invaded by capillaries and osteoblasts The osteoblasts form trabeculae about central canals—hereby forming the osteogenic tissue in which calcium salts are deposited (Watson Jones 1952 Boyd 1961) This proliferation of osteoblasts can be observed in studies using bone seeking isotopes—which are metabolised in the organism in the same manner as calcium—as an increase in activity measured over the fracture zone (Bauer & Wendeberg 1959)

The ratio of activity over the fracture to activity symmetrically over the normal extremity varied during the process of healing having two distinct maxima

The first maximum was found within the first weeks after trauma corresponding to an especially large proliferation of osteoblasts at this time (Watson Jones 1952) This increase in activity shortly after the occurrence of a fracture has also been observed by Myers & Olejar (1963) in a study with ^{85m}Sr healing of tibia and fibula fractures in rats

The increase in activity is localised in a relatively restricted region (Bauer & Wendeberg 1959) so that it was possible to follow variations during the healing process in a patient with bilateral fractures one located medially on the one side and the other distally on the opposite side

With the commencement of stressing a functional adaptation to the primary bone tissue takes place with a reorganisation of the bone lamellae In conjunction with this rearrangement of the bone structure

a further proliferation of osteoblasts occurs A renewed increase in activity over the fracture is observed in the first examination after weightbearing without cast immobilisation indicating that reorganisation first starts at this time no increase in activity occurring when the patient supports on a cast immobilised fracture

The reorganisation of bone structure is a very long process in most patients activity over the fracture was higher than activity over the normal extremity for more than 6 months after the fracture was healed clinically

Complications in fracture healing could not be detected earlier with the isotopic method described than with the usual clinical and radiological examination Activity relationships for patients with delayed healing and pseudoarthrosis were of special interest but were found to be similar to those for patients with uncomplicated healing and gave no information which could help in the prediction of complications However according to Segmüller et al (1970) isotopic methods are able to distinguish between a pseudoarthrosis caused by inadequate osteogenesis and one caused by insufficient fixation

^{87m}Sr has a relatively short half life (2 8 hours) and measurements of activity have to be taken shortly after injection One hour after injection the blood system still contains 50–70 per cent of the injected quantity (Charkes 1969) and consequently there is a strong secondary radiation from the blood system at this time This may explain why the average values for the two maxima for the individual fracture types were increasingly lower with more proximal fracture location since the proportion of soft tissue relative to bone is greater proximally than distally (Bauer & Wendeberg 1959)

In patients with cicatrix infections after complicated fractures or osteosynthesis as well as in one patient with thrombophlebitis a sharp increase in activity over the fracture zone was found at the time of infection This indicated that variations in activity were not caused by a change in the quantity of osteoblasts alone but could be caused by other factors such as changes in blood flow in the vicinity of the fracture

Certain patients were therefore injected with ^{99m}Tc labelled albumin as well as ^{87m}Sr The labelled albumin which is a macromolecule remains in the blood vessels and capillary bed and ^{99m}Tc activity is thus a measure of the blood space An increased blood flow in the fracture zone was found in all cases and the variations in F/N for the two compounds were always found to be parallel

Since studies with injection of both ^{87m}Sr and ^{99m}Tc were restricted to a few patients, there is little basis for definite conclusions, but part of the rise in activity over the fracture zone after ^{87m}Sr injection can probably be attributed to increased blood flow and part of the variation in the ratio F/N is thought to be due to altered blood flow It is therefore necessary to elucidate the effects of changes in circulation before studies of the control of fracture healing with ^{87m}Sr uptake can be continued

SUMMARY

Thirty nine patients with a variety of fractures mainly in the lower extremities, were injected intravenously with 10 μc ^{87m}Sr/kg in 409 separate assays with the intention of supervising fracture healing by external counting 27 fractures healed without complications 8 with complications and 4 patients were regarded as special cases Patients were followed up for an average of 269 days and were checked from 6 to 16 times

In all patients an increased activity was observed over the fracture The ratio of activity over the fracture to activity symmetrically over the opposite normal extremity varied during the healing process Two maxima occurred consistently one between day 8 and day 32 after the initial lesion the other between day 8 and day 15 after weightbearing without plaster fixation The initial maximum was delayed in proportion to increasing complexity of the fracture The average values of both maxima were higher the more distal the location of the fracture

Complicated fracture healing could not be detected earlier with isotopic examination than with the usual clinical and radiological examination Large increases in activity over the fracture zone were observed in cases of infection in the vicinity of the fracture

The effects of blood flow were investigated in a number of cases by injecting patients with ^{99m}Tc labelled albumin together with ^{87m}Sr In all cases an increased blood flow was found in the vicinity of the fracture and part of the variation in the ratio of activities over the fracture and symmetrically over the other extremity after injection of ^{87m}Sr could be attributed to changes in blood flow in the vicinity of the fracture

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DOES DIPHENYLHYDANTOIN ACCELERATE HEALING OF FRACTURES IN MICE?

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Administration of the anti convulsant drug diphenylhydantoin frequently causes hyperplasia of the gingiva (Ziskin et al 1941) In such hyperplastic tissue collagen synthesis is increased (Shapiro 1958 Stern et al 1943) resulting in faster healing of gingival wounds (Shapiro 1958) Increased collagen synthesis has also been demonstrated in the skin of diphenylhydantoin treated rats (Houck et al 1960 Houck 1962) healing was accelerated (Kelln & Gorlin 1961 Shafer et al 1958) as reflected by an increased tensile strength of the wound in early stages of healing Furthermore human and animal fibroblast like cells in tissue cultures have shown an increased proliferation rate when diphenylhydantoin was added to the culture medium (Shafer 1960 Shafer et al 1961)

The purpose of the present study was to find out whether stimulation of collagen synthesis by diphenylhydantoin has any effect on the rate of healing of fractures in the lower hind legs in young mice The following variables were studied (1) Tensile strength of the fracture callus after a healing period of 9 days and the breaking strength after 21 days (2) Uptake of radioactive strontium (Sr) in the fracture callus after a healing period of 9 or 21 days (3) Concentration and solubility of collagen in the fracture callus

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MATERIAL AND METHODS

Eighty male albino mice about 4 weeks old and weighing 18–22 g were used. The animals were divided into 2 experimental and 2 control groups of 20 animals each. They were kept in separate cages and fed a standard laboratory diet and allowed water *ad libitum*. The experimental animals received a daily i.m. injection of diphenylhydantoin (Difydan, Leo Inc., Helsingborg, Sweden) 50 mg/kg body weight dissolved in 0.2 ml of a solution composed of 20 per cent ethylene glycol and 10 per cent ethyl alcohol to which sodium hydroxide was added until the substance was dissolved at pH 11.8. The control animals received the solvent solution according to the same schedule. The drug and the solvent were stored frozen (−20° C) and the daily doses were thawed just before injection.

In all experimental and control animals the middle of the left tibial diaphysis was manually fractured under ether anaesthesia on the third day after the *beginning of the treatment*.

Determination of the tensile strength of fracture callus

Nine days after fracture one of the two experimental groups and one of the two control groups were weighed and sacrificed. Their fractured tibiae were immediately dissected free from the fibula and soft tissues and the tensile strength of the fracture callus was measured with a spring balance (Mess & Weg Technik, Wennigsen, West Germany) attached to the ankle joint by a thread sling with the lower hind leg hanging from another thread sling through the knee joint (Figure 1). The balance was loaded in the direction of the long axis of the bone until the bone ends were separated at the fracture level. The force necessary to bring about this separation was recorded as "the tensile strength" of the fracture.

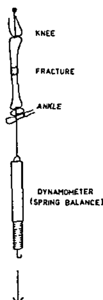
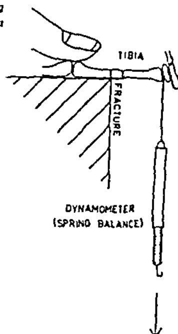


Figure 1. *Experimental conditions for measuring tensile strength of healing fractures of the tibia in mice.*

Figure 2 Experimental conditions for measuring breaking strength of healed fractures of the tibia in mice



Determination of the breaking strength of fracture callus

The animals in the remaining experimental group and control group were weighed and sacrificed on the 21st day after fracture The left hind legs were X rayed and dissected free from soft tissues and from the fibula at the level of the fracture The breaking strength of the fracture calluses were immediately determined with the same balance (Figure 2) which was now fastened by a thread sling over the frontal side of the ligaments of the ankle joint with the tibia firmly pressed against a tabletop with the fracture callus at the edge The balance was loaded perpendicular to the long axis of the bone until it fractured the bony callus The load necessary to produce this fracture was recorded as the "breaking strength"

Determination of the 24 hour uptake of ^{85}Sr

Twenty four hours before sacrifice every experimental and control animal received an equal dose of about 1 μCi ^{85}Sr in an i m injection of 1 ml aqueous solution of strontium nitrate After determination of the tensile or breaking strength the fracture callus was dissected under a dissection microscope weighed (wet weight) and 10 calluses from each set were used for measuring the uptake of ^{85}Sr The activity was determined with a Well type scintillation detector and compared with the simultaneously registrated activity of a standard solution of 1 per mille of the injected doses. Afterwards the calluses were ashed for 24 hours at 560 C and the ash was again weighed (ash weight) The "specific activity" of the individual calluses was calculated as cpm of the sample per mg ash as per mille of injected dose and corrected for background activity

Determination of collagen concentration and solubility in fracture callus

In connection with the dissection the remaining 10 calluses from each set were transferred to acetone and dehydrated in this liquid for 7 days with daily changes of the acetone The material was then weighed (dry weight) and homogenized in 6 ml of 5 M NaCl solution in an ultra turrax homogenizer (Janke & Kunkel KG Staufen i Br West Germany) The homogenized tissue was then extracted in a shaking machine, centrifuged and washed twice with 2 ml 5 M NaCl The pooled supernatant obtained by this procedure was called the salt soluble fraction The precipitate was afterwards homogenized in 6 ml cold 5 M citric acid buffer (pH 3 6) extracted for another 24 hours centrifuged and washed in the same way The combined supernatants and the precipitate after these extractions were called the acid soluble and insoluble fractions respectively The different soluble and insoluble fractions were then hydrolyzed in 10 ml 6 M HCl by autoclaving in 130 C for 4 hours and the hydroxyproline content was determined according to Woessner and used as an expression of the collagen content The total hydroxyproline concentration was calculated as the sum of the content of hydroxyproline in the fractions of different solubility In previous experiments this calculation had been found to include an error of less than ± 5 per cent

Statistics

Standard statistical methods were used. Probability levels exceeding 5 per cent are referred to as significant

RESULTS

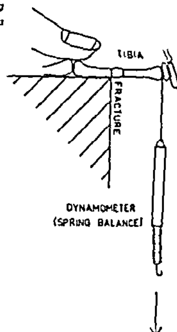
There was no difference in weight gain between the diphenylhydantoin treated and the control animals (Table 4)

After the healing period of 9 days all fracture calluses were still unstable and the fracture ends were held firmly together by callus consisting mainly of fibrous tissue and cartilage After 21 days the fractures were clinically stable the stabilizing callus consisting mainly of mineralized osteoid trabeculae with marrow cells scattered among the trabeculae The macroscopic histologic and X ray appearance of the healing fractures was independent of the treatment given

The tensile strength of the fracture calluses 9 days after fracture was markedly increased on the experimental animals treated with diphenylhydantoin (Table 1) The breaking strength of the fractures after a healing period of 21 days was also significantly increased in the experimental group (Table 1)

Between wet weight and tensile strength of the fracture calluses there was a significant positive correlation (01>p> 001) There was however no correlation between animal weight and tensile strength of the fracture whether the animal had been treated with diphenyl

Figure 2 Experimental conditions for measuring breaking strength of healed fractures of the tibia in mice



Determination of the breaking strength of fracture callus

The animals in the remaining experimental group and control group were weighed and sacrificed on the 21st day after fracture. The left hind legs were X-rayed and dissected free from soft tissues and from the fibula at the level of the fracture. The breaking strength of the fracture calluses were immediately determined with the same balance (Figure 2), which was now fastened by a thread sling over the frontal side of the ligaments of the ankle joint, with the tibia firmly pressed against a tabletop with the fracture callus at the edge. The balance was loaded perpendicular to the long axis of the bone until it fractured the bony callus. The load necessary to produce this fracture was recorded as the "breaking strength".

Determination of the 24 hour uptake of ^{85}Sr

Twenty four hours before sacrifice every experimental and control animal received an equal dose of about 1 μCi ^{85}Sr in an i.m. injection of 1 ml aqueous solution of strontium nitrate. After determination of the tensile or breaking strength the fracture callus was dissected under a dissection microscope, weighed (wet weight), and 10 calluses from each set were used for measuring the uptake of ^{85}Sr. The activity was determined with a Well type scintillation detector and compared with the simultaneously registrated activity of a standard solution of 1 per mille of the injected doses. Afterwards the calluses were ashed for 24 hours at 560 °C and the ash was again weighed (ash weight). The "specific activity" of the individual calluses was calculated as cpm of the sample per mg ash as per mille of injected dose and corrected for background activity.

solutions was very low and not measureable (below 01 mg hydroxy proline per g callus) in the control samples In the experimental samples however there were low but measureable quantities of both salt and acid soluble collagen (Table 2)

The 24 hour uptake of ^{85}Sr (specific activity) was about the same in all calluses irrespective of healing time or treatment given (Table 3) The wet weight/ash weight ratio was also independent of the treat ment given but was significantly higher after a healing period of 9 than after 21 days (Table 4)

Table 3 *Specific activity* $\frac{\text{cpm (sample)}}{\text{cpm (standard} = 1 ‰ \text{ of dose)} \times \text{mg ash (sample)}}$ *of fracture callus in diphenylhydantoin treated (experimental) and control mice*

Period of healing Days		9	21
Specific activity of fracture callus ± SE	Experimental specimens	2 34± 39	2 84± 38
	Control specimens	3 14± 42	2 94± 46
Significance of difference (student s t test)		P>5%[1]	P>5%[1]

Table 4 *Weights of experimental (diphenylhydantoin treated) and control specimens On no occasion was there any significant weight difference between experimental animals or samples*

Period of healing Days		0	9	21
Body weight of experimental animals Mean (g)±SE		18 9± 49	21 7±1 38	24 5± 74
Body weight of control animals Mean (g)±SE		18 5± 51	2[illegible] 2±1 32	25 3± 78
Wet weight of fracture callus Mean (mg)±SE	Experimental samples		42 1±5 8	45 5±4 0
	Control samples		34 8±3 2	37 8±3 0
Ash weight of fracture callus Mean (mg)±SE	Experimental samples		4 [illegible]8± 63	9 09±1 76
	Control samples		4 08± 65	7 9 ±1 85
Wet weight/ash weight	Experimental samples		9 8	5 0
	Control samples		8 5	4 3

DISCUSSION

The improved fracture healing in animals treated with diphenyl hydantoin as documented by the higher mechanical strength of the callus of healing and healed fractures in mice is in agreement with previous findings of earlier organized fracture haematomas in the mandible of rabbits treated with diphenylhydantoin (Sklans et al. 1967). The organic matrix of bone is to more than 90 per cent composed of collagen (Eastoe & Eastoe 1954, Mills & Bavetta 1968). Diphenyl hydantoin has been shown to stimulate the synthesis of collagen in various tissues (Houck et al. 1960, Shafer et al. 1961). This higher rate of synthesis of collagen may therefore contribute to the better healing of fractures in animals treated with this drug. The amount of collagen extracted from the fracture callus with a neutral salt or dilute acid buffer solution was larger in the animals treated with diphenyl hydantoin. This observation, indicating a lesser degree of cross linking in this material, may be related to an increased synthesis of collagen in the healing bone tissue of the diphenylhydantoin treated animals (Jackson & Bentley 1960). Readily extractable collagen includes recently synthesized collagen and degradation products (Jackson & Bentley 1960, Laitinen 1967). Future investigations with the aid of radioisotopes may perhaps produce more convincing evidence of increased collagen synthesis in the healing bones of diphenylhydantoin treated animals.

There was no difference in the mineral uptake by these calluses as measured by the 24 hour uptake of Sr. Neither was there any difference in the concentration of mineral (ash weight/wet weight ratio) in the fracture calluses of different maturity between the diphenyl hydantoin treated and control animals. With these parameters there was thus no measureable difference in the mineralization pattern of the experimental and control samples. In our estimation of "the specific activity" of the calluses the uptake of Sr was recorded in relation to the ash weight of the sample. The higher ash content of both the experimental and control specimens taken 21 days after fracture (Table 4) implies about a twofold increase in the uptake of radioactivity after 21 days than after 9 days. This result is in accordance with that of Lemaire (1966) and of Stacher & Firschein (1967).

There was a non significant difference in the mean wet weight and ash weight of the calluses, which were heavier in the experimental animals both 9 and 21 days after fracture. Dissection of these small

samples gave rather large individual differences (Table 4) despite the use of the dissection microscope The weight differences were not statistically significant but the fact that the mean weight of the experimental specimens was higher on all four occasions suggested that the difference found was a true difference If it was diphenylhydantoin may act on bone healing by increasing the size of the fracture callus the mechanical strength being a measure of callus mass rather than quality

Diphenylhydantoin is a well known drug that has been used in the treatment of epileptics for more than 30 years (Kelln & Gorlin 1961) Its toxicity is low (Geever et al 1967) The dosage used was about 4 times higher than recommended for humans Considering the higher metabolic rate in mice this dose may be comparable with that used in antiepileptic treatment of human beings No toxic effects of the drug were observed Furthermore the animal weight gain was normal and equal in the experimental and control groups (Table 4)

Diphenylhydantoin however has other effects on skeleton and metabolic reactions It is known to depress the secretory activity in a number of endocrine glands (Pento et al 1972) including inhibition of insulin release (Levin et al 1970 Malherbe et al 1972) and calcitonine release (Pento et al 1972) Recent investigations have also shown that diphenylhydantoin as well as other anticonvulsant drugs may cause an alteration of the calcium metabolism in the skeleton resulting in osteomalacia after long term therapy (Dent et al 1970) Subnormal serum calcium levels and raised serum alkaline phosphatases have been observed (Richens & Rowe 1970) These effects have been attributed to liver enzyme activation causing accelerated breakdown of vitamin D (Richens & Rowe 1970 Hunter et al 1971 Wright 1965) A therapeutic agent which also causes an increased metabolism of collagen in the skeleton may cooperate with the disturbed calcium metabolism resulting in even faster decalcification of osteomalaic bone As a matter of fact osteomalacia induced by anticonvulsant drugs has mainly been described in connection with treatment by diphenylhydantoin and chemically related compounds

The stimulating effect of diphenylhydantoin on the synthesis of collagen and its stimulating effect on healing of connective tissues has been demonstrated in different species (Houck 1962 Kelln & Gorlin 1961 Kolbert 1968) including man (Simpson et al 1965) Thus there is reason to believe that diphenylhydantoin may improve fracture healing also in other vertebrates In fact diphenylhydantoin has been reported to increase the healing rate of chronic leg ulcers in humans (Simpson et al 1965)

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URINARY HYDROXYPROLINE EXCRETION IN OSTEOMALACIA

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Accepted 20 i.73

Ever since Westall (1955) first noticed the presence of hydroxyproline in the urine of normal persons urinary hydroxyproline excretion in normal individuals and its significance in different diseases has been a subject of extensive investigations It has been shown to vary with age and sex It is increased in several disorders of bone metabolism such as hyperparathyroidism hyperthyroidism acromegaly Cushing syndrome metastatic bone disease etc (Bonadonna et al 1966 Dull & Henneman 1963 Laitinen et al 1966 Lee & Lloyd 1964) In osteomalacia (Klein & Curtiss 1964 Kowalessar et al 1964) there have been stray reports of increased excretion of hydroxyproline in urine The purpose of this study was to establish whether there was any significant difference in the urinary hydroxyproline excretion in osteomalacia as compared with suitable controls

MATERIAL AND METHODS

Proven cases of osteomalacia were selected for this study the diagnosis being established by standard biochemical radiological and histological criteria. They were kept on meat and collagen free diet for three days Apart from routine haematological urine and stool examinations their serum calcium phosphorus and alkaline phosphatase estimations were done and their urine was collected. Urine from suitable healthy age and sex matched controls was similarly collected. In all 31 controls and 38 patients with osteomalacia were studied. Urinary hydroxyproline was estimated by the method of Prockop & Udenfriend (1960) Urinary creatinine estimation was also done in a few cases

RESULTS

Total hydroxyproline excretion in 24 hours was studied in 30 controls and 28 patients (Table 1)

Table 1 Total urinary hydroxyproline excretion in urine per 24 hours in controls and osteomalacia.

	Min	Max	Mean	S D	S E
Control	*9 81*	*112 50*	*3? 97*	*21 93*	*4 0038*
Osteomalacia	39 00	410 00	121 2857	87 113	16 462

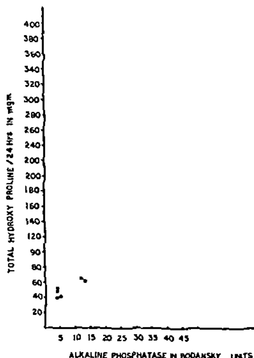


Figure 1 Showing the correlation between serum alkaline phosphatase and total hydroxyproline excretion in urine in mg/24 h (r = 3803 P < 05)

The total hydroxyline excretion in 24 hours was significantly higher in osteomalacia than in controls (t = 20 0918 P< 001) Further the total hydroxyproline excretion was found to correlate well with the serum alkaline phosphatase values in these patients (Figure 1)

In order to avoid pitfalls of 24 hour urine collection the hydroxyproline/creatinine ratio was calculated in 28 controls and 31 osteomalacia patients (Table 2)

Table 2 Hydroxyproline/creatinine ratio in urine of controls and osteomalacia

	Min	Max	Mean	S D	S.E
Control	0171	10J7	0488	0259	0049
Osteomalacia	0400	0600	2100	1510	0271

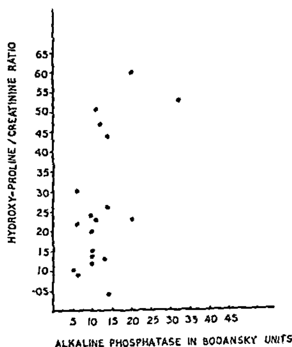


Figure 2 Showing the correlation between serum alkaline phosphatase and hydroxyproline/creatinine ratio (r = 4922 P < 01)

The difference between the two groups was statistically significant (t = 3 9035 P< 001) The hydroxyproline/creatinine ratio in these patients was found to correlate well with the serum alkaline phosphatase values (Figure 2)

DISCUSSION

Urinary hydroxyproline excretion in healthy adults on meat and collagen free diet is fairly constant, though it may vary quite a bit from one individual to another The urinary hydroxyproline is derived mainly from body collagen in such healthy persons The relationship between

urinary hydroxyproline excretion and bone collagen metabolism has been fairly well established Dull & Henneman (1963) are of the opinion that the measurement of urinary hydroxyproline excretion may provide a rapid and useful index to the metabolic activity of bone matrix in various diseases Clinical studies have shown it to be high in diseases where bone matrix is metabolically more active

In the present study the total urinary hydroxyproline excretion in 24 hours shows a wide scatter in the control series the maximum being as high as 112 50 mg However the mean value is 32 97 mg which compares well with other published series Both the 24 hour urinary hydroxyproline excretion as well as the hydroxyproline/creatinine ratio were significantly higher in osteomalacia as compared to the control group This indicates that the bone matrix in osteomalacia is metabolically more active Whether this rise is due to increased bone resorption as held by many authors (Benoit et al 1963 Bonadonna et al 1966 Smith & Nordin 1964) or to increased bone formation as suggested by some (Klein et al 1966) is difficult to say The correlation between the total hydroxyproline excretion as well as the hydroxyproline/creatinine ratio with the serum alkaline phosphatase in the present study suggests that urinary hydroxyproline excretion reflects bone formation

SUMMARY

1 Total hydroxyproline excretion in urine per 24 hours was studied in 28 patients suffering from osteomalacia and 30 controls It was significantly higher in osteomalacic patients

2 Hydroxyproline/creatinine ratio was calculated in 28 controls and 31 osteomalacic patients This was also significantly higher in the latter

3 Both total hydroxyproline excretion per 24 hours and hydroxyproline/creatinine ratio correlated well with the serum alkaline phosphatase values in osteomalacic patients

ACKNOWLEDGEMENT

The hydroxyproline estimation was done in the Surgical Research Laboratories of the Institute of Medical Sciences Banaras Hindu University for which I am grateful to Prof K N Udupa Director of the Institute of Medical Sciences and Senior Superintendent S S Hospital B H U I am also thankful to him for permission to study and publish this report

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GANGLION CYSTS OF BONE

Report of Two Cases and Review of the Literature

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The occurrence of subchondral bone cysts was first noted by Hicks in 1956 Since then 51 cases have been reported The purpose of this paper is to describe an additional two cases having similar clinical and histological features with a review of the literature

CASE HISTORIES

Case 1 A 47 year old man presented with a 4 year history of pain at the lateral aspect of his left knee with limping and increasing disability There was no locking or giving away of the joint Clinically there was tenderness and mild swelling over the left fibula X rays revealed a cystic lesion of the proximal fibula with a thin sclerotic border (Figure 1) Laboratory analysis was normal At operation after fenestration of the fibula there was an outpouring of thick mucoid fluid The lesion was curetted Histologically the lining of the cyst resembled a ganglion cyst The curettage resulted in a relief of the complaints

Case 2 A 45 year old man had noted intermittent aching discomfort in the left ankle for two years His symptoms were accentuated by activity X rays revealed a cystic lesion located at the medial malleolus (Figure 2) At operation the cyst had a whitish lining and was filled with myxomatous material typical of a ganglion cyst The lesion was curetted with good results Histologically the wall of the cyst exactly simulated that of ganglion cyst of soft tissue (Figures 3 and 4)

DISCUSSION

Typically this lesion is encountered during middle age The cases reported range from an 18 year old (Nigrisoli 1971) to an 86 year old patient (Sim 1971)

Sex difference is apparently not great enough to be meaningful There is no distinct sex difference



Figure 1 AP radiograph of the left proximal fibula showing a cystic lesion with discrete borders of surrounding sclerosis

The most frequent localisation is at the ankle (Figure 5) The onset of the condition is insidious and the complaints are present for several months sometimes several years before medical attention is sought The patients usually present with aching discomfort related to activity

Laboratory analysis is usually normal X rays show a well defined cystic lesion extending to the subchondral bone with discrete borders of surrounding sclerosis Most of the lesions are unilocular less commonly they are multilocular (Nigrisoli 1971 Sim 1971) Histologically the border of the lesion and the mucoid gelatinous content are identical to that of soft tissue ganglion cysts

Treatment by curettage and bone grafting appears to be effective in two cases treated in this manner (Crabbe 1966 Sim 1971) there has been a recurrence One case recurred six times over a 16 year period (Sim 1971) There is still discussion about the etiology and patho-



Figure 2 AP and lateral radiograph of the left ankle showing a cystic lesion occupying the medial malleolus

genesis of this lesion and its more common soft tissue counterpart Hicks (1956) applied the term synovial cyst in his paper he described a distinct layer of synovial like cells His suggestion about pathogenesis was that skeletal connective tissue undergoes synovial differentiation Crane & Scarano (1967) also used the term synovial cyst to refer to cysts occurring in relation to joints and tendons They postulated a defect in the articular surface with either simple extrusion of synovial fluid or proliferation of the synovial membrane through the



Figure 3 This is a low power photomicrograph of the lining of the cystic lesion (× 27)

defect They demonstrated in their cases strips of tissue arrangement which fairly closely resembled synovial membrane

Most authors did not describe a distinct layer of flattened synovial like cells At operation a communication between the cystic bone lesion and the articular cavity was only observed in four cases (Scaglietti 1960 Crane 1967 Nigrisoli 1971) This does not rule out that there has been or is a small connection in the other cases

Histologically the appearance of these lesions may be similar to that of the cysts found in osteoarthritis In their study of osteoarthritis Harrison et al (1953) concluded that the cysts are the results of small foci of bone necrosis the result of infarction occurring at pressure areas and that communication with the articular cavity and the pressure of the joint fluid prevented healing

To Ferguson (1964) the histological findings suggested trabecular fractures repair callus was formed and clefts appeared within the repair tissue In the older clefts the wall thickened and a process very akin to ganglion formation takes place Smaller cysts coalesce to form larger ones

Figure 4 Detail A shows a dense fibrous wall of the cyst with a more myxomatous component to the centre of the cyst (× 70)



Figure 4 Detail B thick collagenous fibrous tissue (× 170)

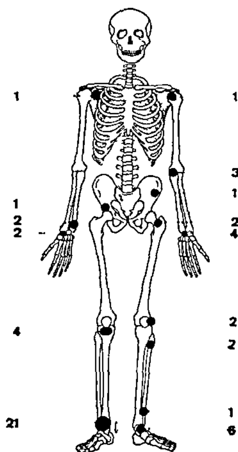


Figure 5

Neither in our cases nor in those reported by the other authors was there any evidence of a degenerative joint disease The hypothesis of vascular disturbance by Woods (1961) must also be discarded Indeed a careful study of all the cases reported by different authors has failed to reveal any evidence of bone necrosis nor was there any fibrosis of marrow on the outside of the cyst

In view of the very close macroscopical and histological similarity to simple soft tissue ganglia it is deemed reasonable to regard this condition as an exactly comparable condition occurring in bone Ritschl (1895) Thorn (1896) and Ledderhouse (1925) agreed that connective tissue may undergo degeneration as a result of chronic damage and liquefaction A study in depth has been performed by Soren (1966) who reported on 200 patients with soft tissue ganglia This author

described the various stages leading to formation of a lesion which is grossly and histologically similar to the subchondral bone lesion. In the initial phase collagen fibers of loose connective tissue are swollen, bifurcated and fragmented. Small cavities develop with myxoid degeneration; some of them coalesce by liquefaction of interposed septa to form a larger cavity which contains mucoid material. In the final stage the degenerative process of the inner wall of the lesion stabilizes. The rim of the lesion becomes broader by proliferation of collagen bundles. Sometimes fibrocytes lying along the inner wall of the cavity form an incomplete lining of flattened synovial like cells.

The etiology of this lesion has not yet been elucidated. The majority of all the reported cases have no history of trauma. Soren (1966) suggested that intensive use of limbs or joints may cause excessive stress in connective tissue, which may undergo degenerative changes. Besides this there must be a constitutional weakness of connective tissue; some patients display multiple soft tissue ganglia. Further biochemical and immunological investigations of connective tissue in patients with soft tissue or bone lesions will probably elucidate the etiology of these lesions.

SUMMARY

The clinical, radiological and pathological features in two cases of subchondral bone cyst are described. Various hypotheses on etiology and pathogenesis of the lesion are discussed. It seems reasonable to regard the soft tissue lesion as an exactly comparable condition to the one occurring in bone. The etiology has not yet been elucidated. Excessive stress and a constitutional factor seem to be important in the etiology. A cystic degeneration of loose connective tissue might be mentioned.

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INTERVERTEBRAL DISC CALCIFICATION WITH COMPLETE PROTRUSION INTRASPONGIALLY

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Accepted 21 ii 73

Calcification of the intervertebral disc which was first described by Calve & Galland in 1922 is relatively common in adults Its incidence increases with age The condition is considerably less common in children (Bjelkhagen & Gladnikoff 1957)

In adulthood the changes are localised in the region of the lower thoracic spine and lumbar spine The etiology of intervertebral disc calcification is not known It has been assumed that difference in vascularisation at different ages is the reason for the age related changes in the manifestation of the condition (Schorr & Adler 1954) The intervertebral disc has a good circulation until the age of 10–20 years after which it becomes conspicuously poorer Trauma over strain changes due to old age and disturbance in the calcium metabolism have been suggested as etiologic factors in calcification of the disc A traumatic etiology is clear in some individual cases (Eyring et al 1964 Sandstrom 1951 Taylor 1966)

Most of the calcifications are completely asymptomatic Symptoms that may occur are pain limitation of movement and local tenderness Elevation of temperature and the sedimentation rate as well as leuko cytosis are sometimes seen in children (Walker 1954)

A calcified intervertebral disc may prolapse like a normal disc Posterior lateral and also anterior prolapse of calcified disc has also been reported (Caffey 1961 Maccartee et al 1972 Walker 1954 Williams 1954)

CASE REPORT

The patient was a fitter aged 55 He had been in good general health A month before admission the patient had felt pain around the lower part of the thoracic spine. The pain radiated piercingly to the ventral side of the thorax Roentgenologic



Figure 1 Radiograph showing calcification in intervertebral disc Th 10–11 Height of the intervertebral space 10 mm

examination (Figure 1) revealed an extensive calcification chiefly in the region of the nucleus pulposus in intervertebral space Th 10–11 The patient s general condition was good the ESR and leukocyte count were normal The long dorsal muscles were tense and there was some limitation in bending the back Roentgen therapy was given to the painful region during the following month but without notable benefit Six months after the patient s first visit the pain suddenly disappeared in connection with some slight exertion When he attended for a follow up examination a year later the clinical status was completely normal Roentgenologic examination (Figure 2) showed that the disc calcification previously diagnosed had prolapsed inside the spongiosa of Th 10 The intervertebral space in question had narrowed from 10 to 6 mm during the interval between the examinations (Figures 1 and 2) Tomography (Figure 3) disclosed more distinctly an extensive intraspongiotic hernia containing calcified tissue in Th 10 The calcified mass of tissue had decreased in the interval between the examinations



Figure 2 The height of intervertebral space Th 10–11 is 6 mm Part of the calcified disc has prolapsed into Th 10 a part has become resorbed

DISCUSSION

The main symptoms in this case resembled those described earlier for disc calcification

Calcification of the disc in adults occurs most commonly in the region of the thoracic spine It is interesting that calcified intervertebral discs are less common in the region of the lumbar spine where again prolapse of the disc is most common Prolapse of a calcified disc is regarded as a rare occurrence (Maccartee et al 1972 Williams 1954) The disc calcification symptoms of our patient disappeared probably in conjunction with the prolapse This may perhaps be attributed to the decrease in over pressure in the disc at the time of prolapse The intraspongiotic prolapse described by us has not been reported in the literature



Figure 3 Tomography of the region seen in Figure 2 Disc calcification has prolapsed inside Th 10 The indication of it in Th 10 is an intraspongiotic cavity with sclerosed walls Most of the calcified mass lies in the cavity of the intra spongiosa of Th 10 there is some calcium residue in the disc itself

SUMMARY

The authors report a case of intervertebral disc calcification in a man of 55 years Prolapse of calcified disc tissue into the vertebra is described

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MECHANICS OF ELEVATION OF GLENOHUMERAL JOINT

Its Application in Rehabilitation of Flail Shoulder in Upper Brachial Plexus Injuries and Poliomyelitis and in Replacement of the Upper Humerus by Prosthesis

A K Saha

Accepted 27 ii 73

In man the head neck axis of the humerus is set at an angle of 120 to the axis of the shaft In addition the head neck axis has an angle of retrotorsion open postero medially with the plane passing through the transepicondylar line parallel to the axis of the shaft and which is 20 –30 The evolution of the radial groove depends on the amount of retrotorsion

In quadrupeds the head is set almost on the top of the humeral shaft and the tuberosities have acquired an unusual prominence in conformity with stability of the forelimbs The sagittal plane bisecting the head is perpendicular to the plane passing through the transepicondylar line parallel to the axis of the shaft There is no torsion

The presence of the neck shaft the retrotorsion angles of the humerus the versatile movements of the glenohumeral joint and other causes make the joint unstable during movements (dynamic instability)

The torsion (the complement of the retrotorsion angle) in its evolution is less marked in primates than in man i e that the glenohumeral joint is more unstable in arboreal primates is a paradox Therefore some compensatory mechanism should be present to prevent dislocation in primates

The necessity for study of the mechanism of the shoulder and dynamic stability (Saha 1969 1971) thus becomes apparent As we studied the mechanism of the shoulder we evolved the concept of a zero-position and its applied importance and minimum requirements for elevation of the glenohumeral joint without impairment of the dynamic stability

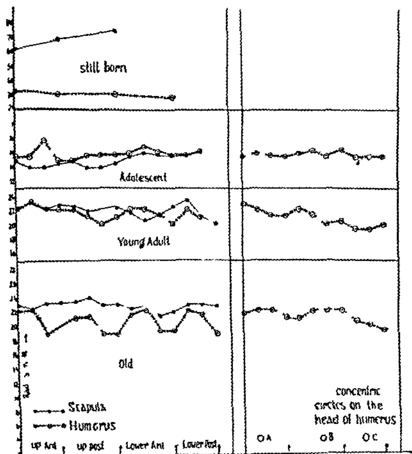


Figure 1 The graphs show the spherometric measurements of the radii of curvature (in mm) of the humoral head and the glenoid cavity in freshly dissected specimens Dotted and continuous lines represent the radii of humerus and glenoid respectively The left hand series give the radii in a stillborn mature baby an adolescent a young adult and an old person taken in four quadrants of the articular surfaces They are irregular and so are not spherical surfaces Disparity between the articular surfaces is not uniform and in one case (adolescent) the radius of curvature of the humerus is greater than that of the glenoid The graphs on the right hand side represent the radii of two concentric bands and a central circle of the head of the same humeri used in the previous determination The radii are more uniform towards the central part of the articular surface than at the periphery

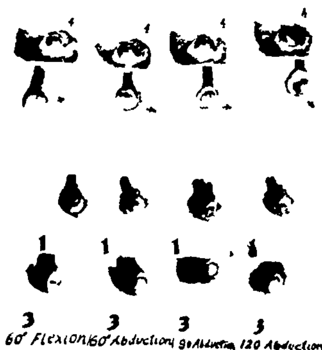


Figure 2 *Lamp-black impression photographs of the glenoid and the humerus in the upper two and of the humerus in the lower two in 60 flexion and abduction and 90 and 120 abduction in a typical Type C joint where the humeral articular surface has greater radius than that of the glenoid The irregular circular bands migrate considerably less with different elevation in the glenoid than they do on the head of the humerus The migration of the contact areas is similar on all the specimens of Type C joint*

Curvature of the joint surfaces (Saha 1958)

Material Freshly dissected and disarticulated glenohumeral joints with incised capsule

Methods Spherometry—special devices are fitted in the three legs and the central rotating pin so that the pressure and weight of the spherometer do not give false readings

Reciprocal lamp black impression of the humeral and glenoid articular surfaces are taken separately while elevating the humerus controlled by identical position of the arm in the living

Conclusions The glenohumeral joint is not a perfect enarthrosis (Figure 1)

There are three types of joints In none of them is the contact between the articular surfaces a geometrical point but a nearly circular

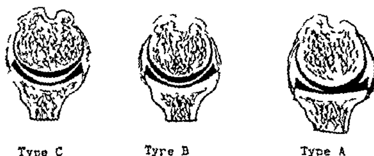


Figure 3 Theoretical concept of three types of joints and their contact surfaces on the basis of Figures 1 and 2 The articular surface has been assumed spherical

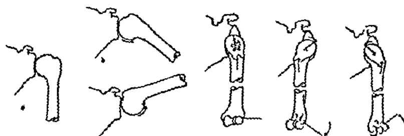


Figure 4 Diagramatical representation of the vertical and horizontal rolling of the head of the humerus in the glenoid These enable change of contact surfaces

area of variable radius In the third type the contact surfaces produce a circular band without any impression on the central part thus proving that the radius of curvature of the glenoid is less than that of the humerus (Figures 2 and 3)

During elevation in multiaxial joints change of contact surface takes place by rolling It is neither a stationary spinning nor a true rolling where the distance travelled by a single roll is equal to the circumference of the sphere The glenoid articular surface on which the head of the humerus *rolls* being limited translatory movement of the head is much less than rotation (Figure 4)

Electromyography (Saha 1958)

Method Simultaneous eight channel electromyographs were taken for eight muscles with coaxial needles during elevation of the arm at uniform angular speed

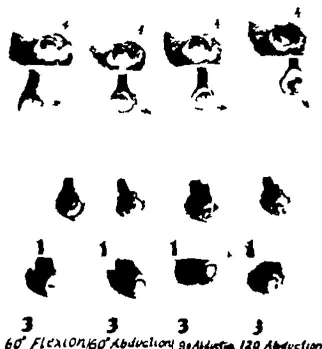


Figure 2 Lamp black impression photographs of the glenoid and the humerus in the upper two and of the humerus in the lower two in 60 flexion and abduction and 90 and 120 abduction in a typical Type C joint where the humeral articular surface has greater radius than that of the glenoid The irregular circular bands migrate considerably less with different elevation in the glenoid than they do on the head of the humerus The migration of the contact areas is similar on all the specimens of Type C joint

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The steerers are arranged at the periphery of an almost spherical articular surface except in the inferior part The direction of the muscle fibres may be assumed to be tangential to the articular surface (sphere) The moment of the force which is tangential to the curvature of the head is the product of the force and the radius of curvature Thus the whole force is spent in rolling the head The inadvertent motion of the distal end follows the rules for a rigid body The angle between the force and the shaft axis when it acts away on the shaft is the sum of the supplement of the neck shaft angle (60) and the inclination of the force to the shaft axis Thus the role of the component tangential to the curve of the head is negligible In this case most of the power magnified by leverage is spent in lifting the arm

The intermediate group of muscles have a certain rotating action even in the zero-position by virtue of their nature of insertion and their role in steering the head is minimal and not essential

It is obvious from the above that the minimum requirements for elevation of the glenohumeral joints are a prime mover a horizontal and a vertical steerer

Dynamic stability in the horizontal direction (Saha 1969 1971)

a) Centripetal force which develops during movement In each case there is acceleration deceleration and uniform angular speed The opposite centrifugal force is balanced by power of the muscles b) Power of the horizontal steerers (subscapularis infraspinatus the upper part of teres minor) c) Anatomical factors Optimum glenohumeral indices i e percentage ratio of the maximum diameter of the glenoid and maximum diameter of the head of the humerus The mean value of vertical index is 75 3 and transverse 57 6 with standard deviations ± 3 9 for vertical and ± 5 6 for transverse These compare favourably with anthropological data

Optimum glenoid tilt—special axial skiagrams are taken to determine the tilt of the glenoid in the living Retrotilt of the glenoid is usual in 73 5 per cent of cases with an average of 7 4 others have either antetilt varying from 2 to 10 or neutral tilt (Figure 6)

Optimum retrotorsion – this is between 20 and 30 and can be determined radiologically in the living Reduced retrotorsion which is very rare produces posterior instability provided there is gross retrotilt of the glenoid Increased retrotorsion produces anterior instability (Figure 7)



Figure 6 Exaggerated posterior tilt of the glenoid in man

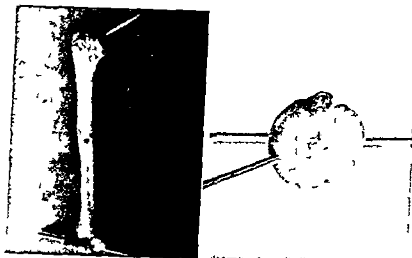


Figure 7 Stillettes are passed one along the axis of the head neck and another through the epicondyles Bird's eye view in the right hand figure shows the retro torsion (complement of torsion angle)

Depth of the glenoid cavity—this factor has not been determined in man but it plays an important part in arboreal primates

Mathematical treatment

Rolling and change of the mechanical axis development of stress in different types of joints role of steerers and development of centripetal force have been confirmed and zero-position of the glenohumeral joint established

1) Steerers are mainly responsible for rolling the head in the socket in different positions of elevation in three directions while the prime mover mainly raises the arm (Saha 1950)

2) Change of mechanical axis takes place by rolling (Saha 1967) With it the instantaneous axis changes in the same direction Sub scapularis (anterior steerer) rolls the head posteriorly (c f pushing) The posterior horizontal steerers infraspinatus and the upper part of teres minor also roll the head posteriorly (c f pulling)

With normal retrotorsion and posterior glenoid tilt the posterior horizontal steerers help the anterior horizontal steerer by developing their power later in the act of elevation The electromyography of these muscles confirms this (Saha 1964 1967)

3) The position during elevation in the coronal and sagittal planes in fact during elevation in any plane where rolling action of the short rotators (steerers) and rotation of the intermediate group of muscles (pectoralis major latissimus dorsi teres major and the lower part of teres minor) are a minimum where the mechanical axis corresponds with the anatomical axis of the shaft where the mechanical axis is in alignment with the scapular spine and is in the newly acquired scapular plane is defined as the neutral or zero position of the glenohumeral joint This is the relative position of the scapula and humerus which is seen in fast moving quadrupeds to give stability to the fore limbs This has brought about structural changes in them the articular surface sits squarely on the top of the shaft like a drum stick In man on the other hand because of the presence of neck shaft angle the contact surface of the humerus in the zero-position will be near the lesser tuberosity with normal retrotorsion Perhaps this position is used by Milch in reduction of dislocation of the shoulder where the three groups of muscles arrange themselves in coaxial cones (Milch 1938)

4) In the third type of joints where there is circular band contact the whole of the stress falls on the anterior glenoid rim during elevation (Saha 1961)

5) Development of a centripetal force which is opposite and equal

to the centrifugal force has been worked out and found responsible to a minor extent for the dynamic stability of the shoulder

Rehabilitation of the flail shoulder following poliomyelitis and upper brachial plexus injury

In a flail shoulder following poliomyelitis and upper brachial plexus injury and birth palsy where all the axio scapulo-claviculo humeral muscles are paralysed and the arthrodesis of the glenohumeral joint is indicated and provided the girdle muscles have adequate power the joint may be rehabilitated with the girdle muscles retaining all its movements The general principles are to provide two steerers vertical and horizontal and a prime mover Their directions should be the same as those of the paralysed muscle fibres and should have adequate power The prime mover is given by transferring the whole of trapezius including the clavicular head to a point as far down the humerus as possible The vertical and horizontal steerers can be provided by levator scapulae and the upper two digitations of serratus anterior (to the top of the greater and lesser tuberosities respectively) Alternatively, the clavicular portion of the trapezius and sternocleidomastoid and pectoralis minor may be used in place of the above In those cases where the retrotorsion is above normal the joint may dislocate anteriorly thus losing range and power due to instability The stability is restored by derotation osteotomy Should latissimus dorsi teres



Figure 8 Functional recovery of the rehabilitated post polio flail shoulder where trapezius was used as a prime mover levator scapulae as a vertical and latissimus dorsi as a posterior horizontal steerer The joint is stable during abduction (vide text) The operation was done in November 19 0

Table 1 Possible live muscles or part of a muscle replacements with their sites of implantation in paralysis of the prime movers and vertical and horizontal steerers in flail shoulder

Paralysis	Replacement	Site of implantation
Prime movers		
Deltoid and clavicular head of pectoralis major	Trapezius	Well down the shaft of the humerus
Vertical steerer	1 Levator scapulae 2 Sternocleidomastoid 3 Clavicular head of trapezius	Top of the greater tuberosity
Horizontal steerers		
Anterior	1 Pectoralis minor 2 Upper two digitations of serratus anterior 3 Residual part of pectoralis major	Lesser tuberosity of the humerus
Posterior	1 Residual part of latissimus dorsi 2 Teres major	Posterior lowest limit of the greater tuberosity

major and portion of pectoralis major have residual power they may be used as horizontal steerers (Saha 1967) If a posterior horizontal steerer is provided by latissimus dorsi the question of instability mentioned above can be adequately compensated without derotation osteotomy (Figure 8) Table 1 shows the possible transfers of live muscles or parts of a muscle These have been tried in flail shoulder following poliomyelitis brachial and birth palsy (Crenshaw 1972)

Prosthetic replacement of upper end of the humerus

In certain cases where the upper fourth of the humerus has to be replaced (e g osteoclastoma) by a prosthesis—it should have the following requirements for proper functioning of the new glenohumeral joint

The upper end of the prosthesis should have the shape of the upper end of the humerus The shaft axis should coincide with the axis of the prosthesis and it should be immovably fixed to the humeral shaft

When fitted the prosthesis should have 5 to 10 of retrotorsion

with respect to the plane passing through the transepicondylar line parallel to the axis of the shaft

Three small tunnels at the site of insertions of subscapularis supraspinatus and infraspinatus for fixing a vertical steerer and any one of the horizontal steerers whichever is convenient Such replacement will enable the arm to be raised overhead without instability

SUMMARY

The mechanism of the shoulder joint has been studied in man with the help of comparative and anthropological studies measurement of curvatures of the joint surfaces simultaneous electromyographic studies in the normal and rehabilitated flail shoulder and mathematical treatment

The study enables us to arrive at the concept of zero position of the shoulder minimal requirements of elevation of the shoulder and hence the rehabilitation of flail shoulder and requirements of a prosthesis for replacement of the upper end of the humerus

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ELBOW WRIST THUMB IMMOBILISATION IN THE TREATMENT OF FRACTURES OF THE CARPAL SCAPHOID

VASILIS TH THOMAIDIS

Accepted 6 ii 73

Fractures of the carpal scaphoid are the most common of the carpal bone injuries amounting to 65 per cent of the fractures and dislocations of all the bones of the carpus Due to the high frequency of delayed union pseudarthrosis and necrosis and the significant disability caused to the wrist joint these fractures have been studied extensively and many methods of conservative and/or surgical treatment have been proposed

This work has been undertaken in order to determine in anatomical specimens optimal position of the elbow wrist thumb immobilisation for the conservative treatment of fresh fractures of the carpal scaphoid As optimal position the one considered was that securing reduction under compression and full immobilisation of the fracture The experience gained by this study was later used for treatment of a series of patients The results obtained by the treatment are reported briefly

MATERIAL AND METHODS

Anatomical specimens of the upper extremities including the shoulder joint from six cadavers were used for the present study Full range of motion existed in the joints of all specimens All muscles of the dorsal surface of the forearm from its middle part down to the middle of the metacarpal bones, as well as those of the radial aspect of the forearm were removed Remaining soft tissues and joint capsule were also removed from the radial half of the wrist The interosseous ligament of the forearm as well as the collateral ligaments of the wrist were preserved.

A transverse fracture at about the middle part of the scaphoid was brought about with an osteotome This type of fracture was chosen as it is the most common in everyday practice (Stewart 1954 Bohler 1956 Russe 1960 London 1961 Watson Jones 1962 Persson 1950)

The material was divided into two groups Three hands were used to study the

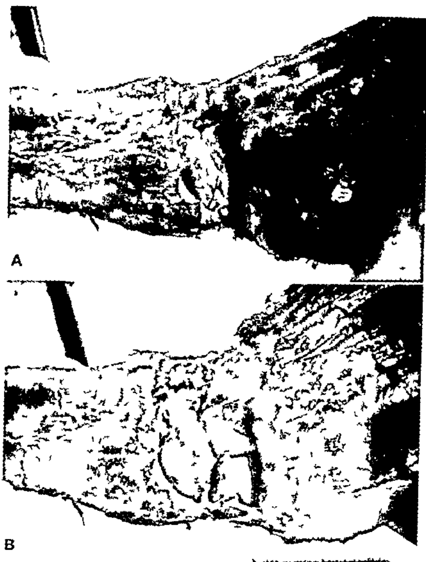


Figure 1 Left hand specimen The fracture brought about in the middle of the carpal scaphoid is seen from the superficial dorsal level
(a) The fracture is reduced by dorsal flexion and radial deviation of the hand
(b) Dorsal flexion and ulnar deviation result in diastasis of the fragments

fracture on either of two levels The superficial dorsal and the deep palmar level In the first group the wrist was integral and the fracture was studied from the dorsal aspect (Figure 1) In the second group the dorsal half of the thickness of the radial part of the carpus together with the adjacent part of the radius were excised with a saw In this way the deep palmar half of the fractured carpal scaphoid was available for study (Figure 2)



Figure 2 The same conditions as in Figure 1 are seen at the deep palmar level of the carpus
(a) Dorsal flexion and radial deviation of the hand reduce the fracture
(b) Dorsal flexion and ulnar deviation result in diastasis between the fragments

The effect of the position of immobilisation on the fracture was assessed by macroscopical observations and roentgenological studies

Position of Forearm—Wrist—Thumb

It was proved in both groups that among different positions of immobilisation optimal reduction and compression of the fragments were achieved with the forearm in middle position i e. the elbow in 90 of flexion and the wrist in 25–30



Figure 3 Radiographic verification of the observations in Figures 1 and 2

dorsal flexion and about 20 *radial deviation* (Figure 1 a and 2 a) *If the radial deviation was changed into ulnar deviation distraction of the fragments occurred* (Figure 1 b and 2 b) This was confirmed by *radiographic observations as well* (Figure 3) Movements of the thumb and first metacarpal bone *resulted in slight* movement of the distal fragment Pronation and supination of the forearm resulted in *obvious movement of the* fracture fragments of the bone in the above mentioned *position of the wrist*

Extent of the Plaster Cast

A cast was applied in the forearm beginning just distal to the elbow *and extending* down to the heads of the four ulnar metacarpal bones *The wrist was immobilised* in about 40 dorsal flexion and 20 *radial deviation The thumb opposing* the third finger was included up to the middle of the distal phalanx *with the first* metacarpal bone aligned with the axis of the radius *Special attention was paid* to the application of the cast on the palm *The forearm was put in mid position* between pronation and supination when the plaster cast was set *Through a small* opening made on the dorsal aspect of the cast *observation of the fracture was* possible With the elbow flexed at 90 *pronation and supination movements were* carried out covering a total arch of about 125 *i e pronation of approximately 55* and supination of 70 *from the mid position This resulted in movement of the* fractured fragments of the scaphoid (Figure 4)

Each of the six specimens was further *pronated and supinated 10 times in a total* arch of 125 -130 In 47 out of *these 60 tests there was clearly visible movement* between the fractured fragments However exact reposition of the fragments was achieved when the forearm reached the mid position suggesting that this position of the forearm is the one of choice for immobilisation In the remaining 13 tests *there was either no visible* movement within the fracture or no reposition of the dislocated fracture



Figure 4 Right hand specimen with fracture of the scaphoid Immobilisation of the hand by a short plaster cast
There is a clear difference in the position of the fracture fragments between maximal pronation (a) and maximal supination (b)

Flexion and extension movements of the elbow (5 –130) with the forearm in mid position did not influence the reduction of the fracture

From these observations it was concluded that the application of a cast including the elbow at an angle of about 90 and the forearm in mid position between pronation and supination is a prerequisite for good retention of the reduced fracture

Clinical Observations

The experience gained from the observations referred to above was applied in the treatment of 25 fresh fractures of the carpal scaphoid during the years 1964–1970 Males 21 females 4 Average age 31 years range 47 and 21 years 19 males and 2 females were laborers

Treatment was initiated in 19 cases 4–15 days after the accident In 4 cases 15–21 days and in each of one case 7 and 9 weeks respectively

Immobilisation was achieved by the use of a plaster cast extended from the middle of the humerus to the heads of the 4 ulnar metacarpal bones and the base of the nail of the thumb A thin layer of cotton was applied before casting the extremity Special care was taken in molding the cast in the palm The elbow was flexed

at an angle of 90 and the forearm was placed in the mid position the carpus in a dorsal extension of about 25 and a radial deviation of about 20 *the thumb* opposite the third finger with its metacarpal bone aligned with the axis of the radius and its joints in slight flexion

Change of the cast and new radiographic examination were performed every 6th week the new cast being placed in identical positions of the joints Immobilisation of the elbow was usually restricted only to 6 weeks The total period of immobilisation of the wrist varied from 8 to 18 weeks Average period of immobilisation 88 days or 12½ weeks

Table 1 The clinical material

Localisation of the fracture	No of cases	Percentage	Healed	Pseud arthrosis	Aseptic necrosis
Middle 3rd	16	64	13	3	–
Distal 3rd	5	20	5	–	–
Proximal 3rd	4	16	2	–	2§
Total	25	100	20	3	2

One case was not submitted to treatment until 7 weeks after the injury
§ One case was not submitted to treatment until 7 weeks after the injury

RESULTS

On a total of 25 fractures of the carpal scaphoid treated according to the principles described above there were 5 or 20 per cent failures i e 3 pseudarthroses and 2 aseptic necroses The latter occurred in fractures of the proximal 3rd of the scaphoid one of which was not submitted to treatment until 9 weeks after the injury (Table 1)

DISCUSSION

Besides the local condition of vascularisation healing of fresh fractures of the carpal scaphoid is largely dependent on a good reduction sufficient compression and adequate immobilisation of the fracture fragments

As to the forearm wrist thumb optimal position for reduction compression and immobilisation of the fracture there is no general agreement Fixation of the wrist in dorsal extension as required for functional position of the hand or formation of fist is commonly advocated (Bohler 1956 Boitzy 1958 Watson Jones 1962 Mazet & Hohl 1963 Broome et al 1964 Mazet 1967 Apley 1968 Broome et al 1968 Goldman et al 1969 DePalma 1970 Persson 1970 Salter 1970)

The position of fixation is not defined by several authors (Wallensten et al 1959 Adams 1969) fixation of the carpus in flexion (Speed 1925) or hyperextension (Hosford 1931) have also been suggested

Fixation of the wrist in dorsal flexion is specially recommended by Stewart (1954) Squire (1959) Verdan (1960) and Verdan & Narakas (1968)

Observations made on cadavers have shown that radial deviation of the wrist promotes the reduction of the fracture and secures good compression of its fragments (Haw 1963) It has been pointed out that fixation of the wrist in radial deviation results in good reduction and compression of the fracture (Friedenberg 1949 Muller et al 1963)

Fixation of the wrist in ulnar deviation is recommended by Bunnell (1956) and Squire (1959) and seems to be suggested by those advocating fixation in "functional position or formation of fist since this position puts the wrist in slight ulnar deviation

Fixation of the wrist in dorsal flexion and radial deviation has been suggested by several authors (Berlin 1929 Sotto-Hall & Haldeman 1934 Sotto-Hall 1945 Friedenberg 1949 Haw 1963)

The conclusions drawn from the present study as to the optimal *position of the wrist between volar and dorsal flexion and radial and* ulnar deviation are in agreement and support the view that fixation of the wrist in dorsal flexion and radial deviation secure optimal conditions for healing of the fracture of the carpal scaphoid

The position of the thumb in the plaster cast is also a subject of dispute The thumb is not included at all in the cast (Friedenberg 1949 Bohler 1956 Russe 1960) or is immobilised in the plaster cast (Stewart 1954 Bunnell 1956 Key & Conwell 1956 Wallensten et al 1959 Broomé et al 1968 Adams 1969 DePalma 1970 Salter 1970) The results of the present study suggest that movements of the thumb and the 1st metacarpal bone resulted in movements of the distal fragment of the fractured scaphoid transmitted through the articulation of the thumb with the greater and lesser multangular bones and are in agreement with earlier observations (Stewart 1954 Key & Conwell 1956 Watson Jones 1962) Fixation of the thumb somewhat flexed in opposition to the 3rd finger with its metacarpal bone aligned to the axis of the forearm and not in abduction has been proved by this work to be optimal for the reduction compression and immobilisation of the fractured scaphoid

There is also disagreement as to the extension of the plaster cast and especially as to the necessity for immobilisation of the elbow joint to

achieve optimal conditions of healing Full immobilisation of the wrist and not the position of immobilisation has been emphasized to be of supreme importance (Bunnell 1956 Bohler 1956 Russe 1960 Watson Jones 1962 Muller et al 1963 DePalma 1970)

The prevailing view today is for the short cast extending from just distal to the elbow to immediately proximal to the heads of the metacarpal bones of the fingers including the 1st metacarpal with or without the thumb with plaster fitted especially well around the palm Inclusion of the fingers in the cast is also supported (Snodgrass 1933 Nenninger 1955)

However the short cast no matter how good the application might be allows movements of pronation and supination of the forearm in an arch varying from 100° to 125 Movements of pronation and supination of the forearm result in movements of the fractured parts of the carpal scaphoid a fact proved on anatomical specimens as well as by radiographic examinations by earlier authors (Verdan 1954 1960 Boitzy 1958 Squire 1959 Frykman 1960 Haw 1963 Verdan & Narakas 1968) and by the present work These observations strongly suggest the necessity for the extension of the plaster cast to include the elbow this is supported by other authors (Broome et al 1964 1968 Persson 1970) Immobilisation of the extremity with the forearm in full supination has also been suggested (Squire 1959 Haw 1963)

The superiority of the results of treatment according to the principles discussed above with regard to the period of immobilisation and the frequency of union as compared with the results of parallel series treated with a short cast' has been pointed out by several earlier authors (Boitzy 1958 Frykman 1960 Broome et al 1964 1968 Persson 1970) No significant difference in the results of similar observation has been reported (Goldman et al 1969)

With regard to the duration of the immobilisation of the wrist until the fracture is healed there is a practical rule accepted by most authors i e that the length of the period of immobilisation needed for healing of the fracture is proportional to the distance of the line of the fracture from the distal pole and/or to the time which has elapsed between the occurrence of the fracture and the initiation of the treatment

Average duration of immobilisation of 10–14 weeks until healing is usually reported much longer durations are also stated for good results as e g 60 weeks (Robertson & Wilkins 1944) 50 weeks (Wallenstein et al 1959) and as much as 26 months (London 1961)

The rate of failures in the conservative treatment of fractures of the scaphoid varies considerably in different reports Thus frequencies as low as 5 to 17 per cent (Stewart 1954 Bohler 1956 Russe 1960 London 1961 Watson Jones 1962 Broome et al 1968) and as high as 40 to 42 per cent (Dickison & Shannon 1944 Adams 1969 DePalma 1970) have been reported

Failure of healing as in delayed union or pseudarthrosis may be attributed mainly to the technique and the time of immobilisation as well as to the time elapsed between the accident and the initiation of the treatment

According to Bohler (1960) a fracture of the scaphoid is considered as fresh up to the 6th week after the injury a time limit which is however arbitrary However for aseptic necrosis in fractures of the proximal 3rd of the scaphoid vascularisation rather than technical factors may be considered responsible for the failure Indeed if there is a disruption of the circulation of the proximal 3rd necrosis occurs regardless of the effectiveness and the prolongation of the immobilisation even in fresh fractures These fractures as well as crush fractures of the scaphoid should actually be disregarded when judging the incidence of failures The same is valid for simple cracks which almost always heal

The present series included 25 complete fractures None of them was a crush fracture and there was no major dislocation of the fragments in any case Healing occurred in altogether 20 cases If for the reasons mentioned above the 4 fractures of the proximal 3rd of the scaphoid 2 of which resulted in aseptic necrosis are excluded then the failure rate in this series will drop from 20 to 14 per cent This fact is considered to support the principles followed in the treatment of fractures of the scaphoid in this series

SUMMARY

Studies have been carried out to determine the optimal position of immobilisation of the wrist and of the extension of the plaster cast for the treatment of fractures of the carpal scaphoid

In 6 anatomical specimens of the upper extremity in cadavers a fracture in the middle of the scaphoid was brought about Studies including macroscopical observations and radiographic examinations were carried out on two different (superficial and deep) levels of the carpus

Full reduction sufficient compression and adequate immobilisation of the fractured bone were secured only when the applied plaster cast included the elbow and the thumb with the forearm in mid position between pronation and supination the wrist in 25 dorsal flexion and about 20 radial deviation and the 1st metacarpal aligned to the longitudinal axis of the radius

Using the experience gained from these studies 25 cases of fracture of the carpal scaphoid were treated according to the described principles Four were fractures of the proximal 3rd of the bone one of which was due to a 9 week old injury This and another case resulted in necrosis of the proximal fragment Among the remaining 21 cases consolidation of the fracture occurred in 18 cases a healing rate of 85 per cent In these cases the mean time of immobilisation was 12½ weeks

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LOW FRICTION ARTHROPLASTY OF THE HIP JOINT AND SEXUAL ACTIVITY

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Accepted 27 ii. 3

It is obvious that severe arthritis of the hip will interfere with sexual function but this is a subject which is rarely discussed with patients and about which little has been written Currey (1970) drew attention to the problem and suggested that total hip replacement was the most successful operation in relieving sexual problems due to osteoarthrosis of this joint However, the number of patients studied was too small for any definite conclusion to be reached

In a recent survey of the results of the Charnley low friction arthroplasty at the London Hospital (Todd et al 1972 Harris et al 1972) the incidence of sexual problems and the influence on this of surgery were analysed

MATERIAL AND METHODS

Information was sought both by interview and by postal questionnaire Of the 292 patients who had undergone arthroplasty 123 (49 men and 74 women) were eligible for study in that they had active sexual relationship at the time of onset of hip joint complaints These patients were questioned about sexual problems and the and 11 others unable to attend for interview were subsequently sent a postal questionnaire similar to that employed by Currey (1970) Seventy nine adequately completed replies were received (58 per cent)

RESULTS

Of those interviewed 11 men (22 per cent) and 36 women (49 per cent) had experienced severe sexual problems which they attributed to hip disease Following hip replacement only 6 men (12 per cent) and 19 women (26 per cent) had severe problems (Table 1) Thus surgery was effective in relieving this problem in nearly half of the patients with considerable sexual difficulties

Table 1 Influence of Charnley low friction arthroplasty on sexual difficulties due to arthritis of the hip

Degree of sexual difficulty	Women Pre op		Women Post-op		Men Pre op		Men Post-op	
Nil	29		44		30		37	
Slight	9		11		8		6	
Considerable	12	49%	4	26%	4	22%	0	12%
Intercourse ended	24		15		7		6	
Total	74		74		49		49	

More detailed information was obtained from the 79 questionnaire replies These came from 36 men aged 30–79 (mean 61) years and 43 women aged 29–78 (mean 60) years Twenty three men (64 per cent) and 37 women (86 per cent) had experienced some form of sexual problem due to hip disease

In the men pain and stiffness of the hip and loss of libido contributed equally to loss of sexual function In the women stiffness was the main cause of disability (in 84 per cent) but pain was also an important factor (Table 2) Three men and 10 women (17 per cent) said that sexual difficulties due to arthritis of the hip had contributed significantly to marital unhappiness and several other patients commented that they were fortunate in having an understanding spouse One woman of 59 said that her marriage could have been saved if operation had been performed a year earlier Following total hip replacement 11 men (48 per cent) and 16 women (43 per cent) experienced considerable relief of their sexual problems (Table 3) This was less dramatic than pain relief which occurred in over 90 per cent of patients and increase in movement which was found in 70 per cent of men and 81 per cent of women

Table 2 Cause of sexual difficulty in those who replied to questionnaire (some indicated more than one reason)

	Women	Men
Patients with sexual difficulty	37	23
Pain in hip	12 (32%)	9 (39%)
Stiffness of hip	31 (84%)	9 (39%)
Loss of libido	8 (22%)	9 (39%)
Uncertain	2	2

Table 3 Effect of Charnley low friction arthroplasty on those patients with sexual problems due to arthritis of the hip who replied to the questionnaire

	Women				Men			
	Relief of sexual problem		Relief of pain		Relief of sexual problem		Relief of pain	
Complete	4	43%	20	95%	6	48%	14	91%
Considerable	12		15		5		7	
Slight	6		1		2		1	
Nil	10		1		9		1	
No reply	5				1			

Of the patients who recognised hip joint disease as a cause of sexual difficulty 70 per cent of the men and 49 per cent of the women would have welcomed advice about this matter. A majority of these favoured a booklet on the subject and a majority also wanted this form of advice for their spouse.

DISCUSSION

At the London Hospital the main indications for total hip replacement have been intolerable pain or severe limitation of movement. It is a salutary lesson that by the time surgery was performed nearly half of the women and a quarter of the men to whom the question was relevant had a severe sexual problem and yet this important aspect of their lives had rarely been discussed with them. When one considers that one sixth of these patients were experiencing significant marital unhappiness on this account and that at least one marriage had broken up for this reason, it would seem important to discuss this aspect of disability when considering a patient for hip surgery. In the younger patients sexual problems due to hip disease may represent a more urgent indication for surgery than pain.

The Charnley low friction arthroplasty is obviously less successful at restoring sexual function than in relieving pain. None the less nearly half of those patients with a serious sexual problem were substantially helped by this operation despite the fact that their average age was about 60 years. Possibly if surgery were performed earlier before sexual relationships had ceased for a long period the operation would be more successful in this respect.

The importance of hip stiffness as a cause of sexual difficulty (Table 2) is a reminder of the disastrous effect that arthrodesis may have on sexual function. This may be a major factor in deciding to perform total hip replacement in a young woman.

Many patients were grateful that this subject was being discussed for the first time. However a significant number of those who actually had a problem did not want any form of advice. The Arthritis and Rheumatism Council (1972) have prepared a booklet which should be helpful to those who want information.

SUMMARY

Of 123 patients who had active sexual relationships at the time of onset of hip joint complaints 11 men (22 per cent) and 36 women (49 per cent) had severe sexual problems which they attributed to hip disease. Following Charnley low friction arthroplasty this problem was relieved in nearly half of these patients. Seventy per cent of the men and 49 per cent of the women with sexual problems would have welcomed advice about this matter—preferably in the form of a booklet.

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FIXATION OF PERMANENT ORTHOPAEDIC PROSTHESIS

USE OF CERAMICS IN THE TIBIAL PLATEAU

STIG LANG, EINAR SUDMANN, SAMUEL F. HULBERT & BARRY W. SAUER

Accepted 28 v 73

It would be of obvious importance if bone tissue ingrowth into porous materials as reported by Hulbert et al. (1971) for ceramics and Lueck et al. (1969) for titanium could be used as a means of attaching load bearing devices to the skeletal system.

For the investigation of the possible use of ceramic materials such as Al_2O_3 implantation in the tibial plateau is near ideal. The compressive forces acting here are not higher than the material can be expected to sustain and the implants are not exposed to tensile stresses and torsional forces which the brittle ceramics can not withstand. Furthermore the cancellous bone of the metaphysis should provide an adequate blood supply for the growth of mineralized tissue at the implantation site. Due to the chemical inertness of Al_2O_3 tissue reactions are not to be expected as stated by Hulbert et al. (1972). However initial attempts to insert ceramic pellets in the tibial plateau of pigs failed due to inadequate strength of the material used (Bhatti & Klawitter 1972). It was therefore necessary to carefully prepare the porous implants.

In this preliminary investigation on dogs pellets of porous alumina were placed unilaterally in the medial tibial plateau of the right knee and the tissue ingrowth was determined upon sacrifice after 6 and 8 weeks.

MATERIAL AND METHODS

Animals

Four adult mongrel dogs, 2 female and 2 male, were used. Their previous history was not known but the animals were all young. The two female dogs both gave birth during the observation period. The mean weight of the four animals was 23.0 ± 4.7 kg.

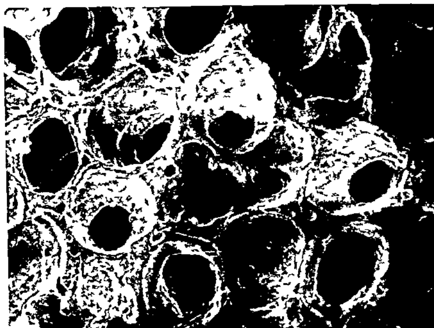


Figure 1 Scanning electron micrograph of the inner pore structure of the implant (× 20)

Preparation of the implant material

A slurry made up of 100 g dry substance (α Al_2O_3, kaolin, talc and $CaCO_3$) in 50 ml 3.5 weight per cent PVA solution (Elvanol 71–30, Du Pont, Willmington, Del., USA) was ball milled overnight to homogenize the mixture. To induce the necessary porosity of the samples 3 ml H_2O_2 (30 per cent) was added to the slurry as well as a decomposition catalyst for H_2O_2. With the addition of the catalyst a fast decomposition was insured. This resulted in a more homogeneous structure of the as cast material.

The slurry was cast in plaster moulds where the decomposition was finished after approximately 10 minutes. The size of the mould was chosen so that it was filled completely with the slurry after the reaction had ended.

A very open porous structure with interconnecting channels was obtained probably due to the highly thixotropic nature of this slurry. This is in contrast to the materials with spherical closed pores usually obtained with this method.

The samples were then allowed to dry overnight at room temperature, followed by 8 hours at 50 °C before firing at 1600 °C in an oxidizing atmosphere. The fired samples had a dense surface layer (the part nearest to the plaster walls) and a porous interior (Figure 1).

The chemical composition of the fired material was

96.0 weight per cent α Al_2O_3, 2.7 weight per cent SiO_2, 1.0 weight per cent MgO, 0.2 weight per cent CaO, 0.1 weight per cent Na_2O etc.

Pellets for implantations were drilled out of the fired samples with a diamond core bore (inner diameter 0 65 cm) The dense intra articular facing surface of the pellet was given a high polish The pellets were about 1 cm long.

Cleaning of the samples and the sterilizing procedure before implanting followed the procedure used by Hulbert et al (1972)

The porous part of the ceramic showed the following structural and mechanical properties before implantation

Pore volume	60 volume per cent (Archimedes density measurements)
Compressive strength	570 kp/cm²
Channel diameter	100–750 μm

Surgical procedure

The right knee joint was exposed through a medial parapatellar longitudinal incision The patella was luxated laterally and the knee joint strongly flexed to provide maximum exposure of the tibial plateau A 0 2 cm pilot hole was drilled perpendicular to the surface of the medial tibial plateau and then enlarged to 0 65 cm to receive the implant All drilling was done under a stream of physiologic saline solution The implant was driven into position using a mallet and nylon driver

The joint cavity was flushed copiously with isotonic saline solution to remove debris before closure The operation incision was closed in layers with non resorbable sutures A topical antibiotic (Furacin Eaton Laboratories Norwich NY USA) was dusted in the incision no dressing was applied Each animal received postoperative intramuscular injections of penicillin (500 000 units) and dihydrostrepthomycin (625 mg) (Penstrep Merck Chemical Division Rahway NJ USA) twice a day for five days

The position of the implant with respect to the surface of the articular cartilage varied somewhat in the four animals operated In dog 1 the implant was slightly angulated in the anterior posterior plane and projected above the surface of the articular cartilage In dogs 2 and 3 the implants were positioned perpendicular to and flush with the articular cartilage In dog 4 the implant was perpendicular to the articular cartilage but recessed 1–2 mm

Radiographs were taken 2 days after operation and thereafter every two weeks Early during the beginning of the postoperative period a radiolucent seam was observed around the pellets On the lateral and medial side this seam disappeared during the observation period on the anterior and posterior side it could be seen throughout the experiment mainly around the upper quarter of the pellets

Histological techniques

At necropsy about 2 cm of the tibial metaphysis including the pellet and the joint surface were retrieved The specimens were immediately placed in buffered formalin and soaked for 24 hours After fixation the samples were dehydrated by successive soaking in 75 95 and 100 per cent ethyl alcohol respectively The specimens were then embedded in monomer methylmethacrylate and left to polymerize at room temperature After complete polymerization excess embedding was trimmed off and 0 5 mm thick longitudinal sections were cut with a diamond precision saw



Figure 2 Wear of the femoral condyle (FC) opposite the ceramic implant (I) The implant is protruding slightly above the tibial plateau

Contact microradiographs of the sections were taken according to a procedure outlined by Jowsey et al (1965) For histological examinations the sections were fixed with epoxy in well slides ground down to a thickness of approximately 55 μm and stained with Paragon 1301 (Paragon PS 1301 Paragon C & C Co Inc, Bronx N Y USA)

For evaluation of the bonding mechanism between new formed bone and implant the distribution of the elements calcium phosphorous and aluminium was determined in the transition layer bone/implant with an Electron probe Micro analyzer Type EMM SM (Applied Research Laboratories Sunland/Ca USA)

RESULTS AND EVALUATION

The dogs started walking a few days after surgery and apparently put weight on the operated limb The gait appeared normal with brief periods of limping No postoperative complications were observed



Figure 3 Microradiograph of the ceramic implant and the surrounding cancellous bone The outer pores especially in the lower part of the pellet are infiltrated with mineralized bone (× 3)

At sacrifice the knee joint of dogs 1 2 and 3 showed a more or less severe wear of the femoral condyle opposite the implant (Figure 2) The knee contained somewhat more synovial fluid than usual 1 3 ml and there was some discoloration of the fluid Dog 4 showed only slight wear of the condyle and the pellet was covered with cartilage The synovial fluid appeared normal

Gross examination of the implants and the surrounding tissue at necropsy showed no signs of an adverse tissue reaction None of the implants showed any visible displacement and they were all solidly anchored to the metaphysis

On all the examined sections the pores of the pellets were filled with tissue (Figures 3 and 4) Mineralized bone was found in the outer 500 μm of the pellets The upper part approximately 1/5 of the implants was surrounded with cartilage and showed an ingrowth of fibrous tissue Some bone resorption may have taken place here possibly due to minor movements of the implant during the observation period

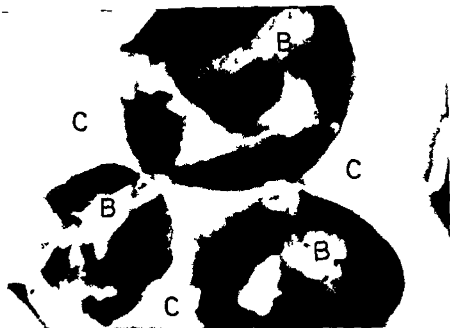


Figure 4 Microradiograph of bone growth (B) in the interior pore system of the ceramics (C) The bone inside the ceramic pores tends to form rings with an inner opening (× 130)

Areas with a direct contact between ceramic implant and mineralized tissue could be found in the histological sections (Figure 5)

Electron microprobe analysis of the distribution of the elements calcium phosphorous and aluminium in these areas confirmed the assumptions of a close contact between new formed bone and implant (Figure 6) The analysis further showed that the new bone inside the porous ceramic contained 80 relative weight per cent calcium and 90 relative weight per cent phosphorous as compared to cancellous bone in the metaphysis near the pellet

However as a rule the mineralized bone was separated from the ceramics with a seam of unmineralized tissue This indicates that the implant material disturbs the crystallization of the mineral phase in bone and that there usually is a lack of bonding forces across the interface If that is the case the mechanical strength of the composite material at the interface bone implant will never be substantially higher than would be expected from the volume fraction of bone present

Figure 5 Fluorescence photomicrograph showing intimate contact between bone B and ceramics C (× 75 Reflected light exciter filter BG 12 barrier filter 53)

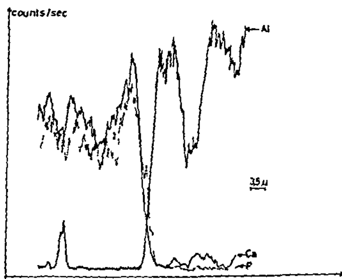


Figure 6 Concentration profiles of calcium phosphorous and aluminium across the interface new formed bone/implant There is no visible transition layer of fibrous tissue between the two phases

SUMMARY AND CONCLUSIONS

Pellets of a porous ceramic material were implanted unilaterally in the medial tibial plateaus of 4 mongrel dogs.

The ceramics contained open pores with a channel connection diameter of 100–750 μm. The compressive strength of a material with 60 per cent porosity was 770 kp/cm

After implantation periods of 6 and 8 weeks respectively the pellets were firmly anchored in the metaphysis due to ingrowth of bone and fibrous tissue. Such ingrowth may therefore be an alternative method for anchoring of functional devices to the musculo skeletal system

The lack of bone formation along parts of the implants might be due to shear forces acting in these areas. A slight movement of the implant may in such cases prevent mineralization. It can not, however, be ruled out that some bone resorption has taken place here. Bone resorption might lead to loosening of the pellets and long term investigations are therefore necessary.

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Figure 5 Fluorescence photomicrograph showing intimate contact between bone B and ceramics C (× 7) Reflected light exciter filter BG 12 barrier filter 53)

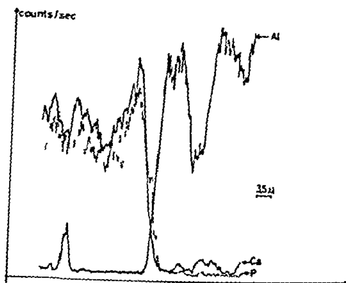


Figure 6 Concentration profiles of calcium phosphorous and aluminium across the interface new-formed bone implant There is no visible transition layer of fibrous tissue between the two phases

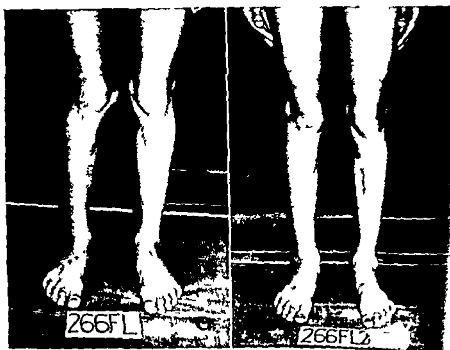


Figure 1 Boy aged 12 years (a) Swelling at the inner side of the ... (preoperative picture) (b) Picture after operat...

direction of the epiphysis produce an ectopic centre D... continues here Later they degenerate and become calcif... atypical ossification centre inside the epiphysis A numb... tion centres arise if cells placed peripherically among... cally localised cells around the epiphyseal ossification... their capacity to divide and ossify The ossification ce... different directions if the cells also lose their polarity...

Local hyperaemy caused by disturbance in innerv... the illness of one side of epiphysis (D Angio et al 19...

Clinical signs

This disorder is usually recognised during the grow... majority of published cases D L H has been most com... and fourteen years of age

The chief clinical sign is the bony hard swelling ... (usually on the inner or outer aspect of the knee ... muscular atrophy may occur as well as restriction ...

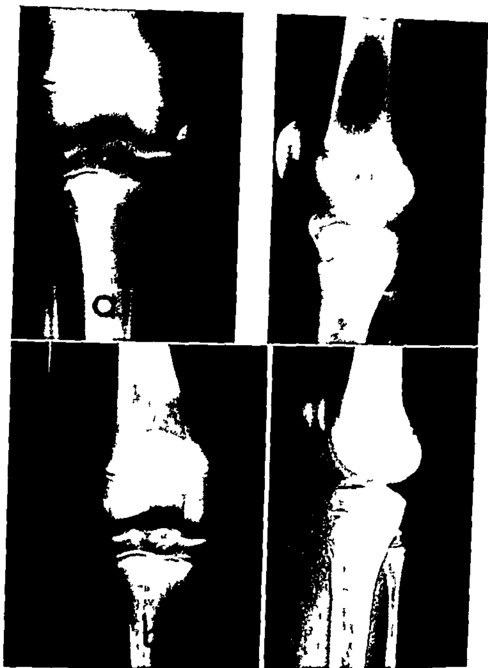


Figure 2 X ray pictures of the right knee (a) X ray picture before operation (b) X ray picture after operation

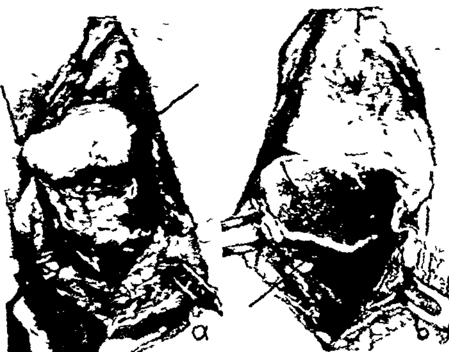


Figure 3 Exposure at exploration (a) Arrow shows the bony lesion (b) The growth cartilage of the tibia can be seen after excision

affected joint The latter is observed if the epiphyseal prominence impinges on the opposing articular surface Because of this varus or valgus deformity may be present There is usually no pain and inequality of limb length Macroscopically the lesion is found to be covered by smooth cartilage as it is seen in osteocartilaginous exostosis There is no sharp borderline between the swelling and the epiphysis

CASE HISTORY

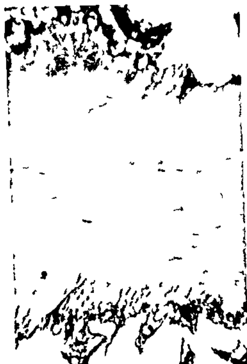
F.L. This 12 year-old boy was admitted with a complaint of slowly growing swelling on his right knee of 3–4 years duration On physical examination a nut sized, bony hard, painless swelling was palpable on the inner aspect of the right knee Motion was free at the knee joint The laboratory findings were normal The X ray picture showed supernumerary growth cartilage on the inner aspect of the epiphysis of the right tibia It was seen to [illegible] proximally from the growth cartilage A sharply outlined [illegible] (is 22 / [illegible]5 mm in size) could be seen in part between the surfaces of the joint (Figure 2 a)

At exploration we observed that the [illegible] nut sized swelling was attached ventrally to the growth cartilage of the tibia by a cartilagic bridge



Figure 4 Ossification centres can be observed in the accessory epiphysis

igure 5 On one side of the super umerary growth cartilage localised between the true piphysis and the accessory one) he cartilage cells produce lines



(Figure 3 a) As the accessory epiphysis and the cartilagic bridge were excised (Figure 3 b) the ligamentum mediale became loose so we had to strengthen it with the ligament of musculus semitendinosus At follow up a year later the patient was free of complaints The X ray picture showed the place of resection (Figure ? b)

Microscopically several ossification centres of different sizes could be observed in the accessory epiphysis These centres were fused with each other and in part with the main ossification centre (Figure 4) An epiphysis plate was found between the epiphysis of the tibia and the accessory epiphysis It could clearly be observed that cartilage cells lined up as is characteristic of the growth cartilage. Calcified areas could be noticed in primary trabeculae (Figure 5) Hypertrophied cartilage cells were found in the cartilage of accessory epiphysis somewhere in a group elsewhere irregularly (Figure 6) The findings are similar to those of osteocartilaginous exostosis

DISCUSSION

About 60 cases of D E H have been reported in the literature The pecial characteristic of the case reported here is an epiphyseal plate between the proximal epiphysis of the tibia and the accessory epiph ysis It is probable that the polarity of cells of the ectopic prolifera



Figure 6 Hypertrophic cartilage cells can be seen in the cartilage cap of the accessory epiphysis

tive cartilage has turned 180 in the vicinity of this area This has resulted in a supernumerary epiphyseal plate because the cells have had different divisional and degenerative tendencies on the opposite sides of the accessory epiphyseal plate

The bony lesion has grown medially rather than proximally This explains why neither valgus deformity nor restriction of motion has occurred at the knee joint The purpose of surgical procedure in this case was to prevent deformity of the joint as well as consecutive arthrosis

SUMMARY

A successfully operated case of D E H (localised to the medial condylus of the right tibia) is reported and the literature is reviewed Etiologic and pathogenetic factors and some hypotheses about the pathomechanism are considered The characteristic of the author's case is the presence of a nearly normal growth cartilage between the epiphysis and the accessory epiphysis

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EFFECT OF OSTEOTOMY ON PAIN IN IDIOPATHIC OSTEOARTHRITIS OF THE HIP

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Accepted 1 iii 73

Numerous reports of the results of follow up examinations after high femoral osteotomies have been published An improvement rate of 60–80 per cent is generally reported (McMurray 1935 Shepard 1960 Robins & Piggot 1960 Harris & Kirwan 1964 Hirsch & Goldi 1968 Bastiani 1969 Salenius et al 1971)

The beneficial effect of the displacement osteotomy has been ascribed to biomechanical alterations of the joint (Pauwels 1963 Knodt 1964, Blount 1964) The main theory claimed that the value of an osteotomy was due to changes in the direction of the mechanical forces acting on the hip joint This effect was achieved by displacement osteotomies

The validity of this mechanical theory was questioned when Nissen (1963) described an osteotomy technique where no gross changes of the biomechanics of the hip joint occurred The results achieved with this non displacement technique equalled those after displacement osteotomies

Pain at rest in the osteoarthritic hip joint has been shown to be correlated with high intraosseous pressures (Arnoldi et al 1972) Further it has been shown that osteotomy resulted in immediate reduction of the high intraosseous pressure concommitant with post operative freedom from pain at rest (Arnoldi et al 1971) In any case these observations put further doubts on the mechanical theories as the sole source of effect of an osteotomy

The effect of osteotomy on pain at rest and on pain on movement was described by Hirsch & Goldie (1968) and mentioned by Salenius et al (1971) No previous study could be found where the results were analysed with respect to distinguishing the effect between displacement and non displacement osteotomies on pain at rest and on pain on movement

Pain at rest is the dull deep ache experienced at rest The intensity of the ache is often correlated with previous activity of the joint but in the severest form it is a constant pain *Pain on movement* is the type of discomfort the patient experiences only when moving the joint with or without weight bearing

The aim of the present follow up examination was to study the effect of different types of osteotomies—one with and two without displacement—on idiopathic osteoarthritis of the hip with particular regard to the effect on pain at rest and on pain on movement

MATERIAL AND METHODS

A total of 161 hips with primary osteoarthritis were treated with high femoral osteotomies during the period 1959–1969 Forty five patients (49 osteotomies) were not examined Fifteen patients had died and 15 were not available for examination In 15 hips some other type of surgery had had to be undertaken due to failure of the osteotomy Thus the final material included in this follow up examination consisted of 112 osteotomies in 101 patients 58 males and 43 females between the ages of 36 and 2 years at operation (mean age 59 2 years)

Operative Techniques

Three different types of high femoral osteotomy have been performed (Figure 1) Each different operative technique was used during a certain period and no preoperative selection of cases for a specific method was made

Method I In use 1959–61 and 1967–69 Thirty six displacement osteotomies Internal fixation with nail and plate. Mean age at operation 57 7 years

Method II In use 1961–64 Twenty seven n n displacement osteotomies according to Nissen (1960) Mean age at operation 59 9 years

Method III In use 1964–67 Forty nine oblique subtrochanteric non displacement

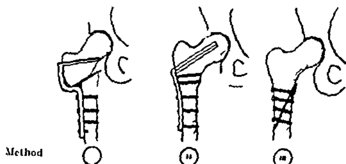


Figure 1 Types of osteotomies

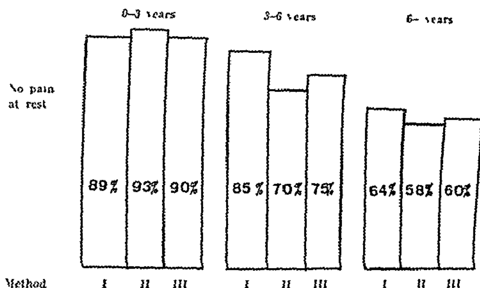


Figure 4 Pain at rest versus observation time

few patients could continue with heavy labour The group performing light work included mainly housewives (Figure 7) No difference exists between methods

Extension—flexion movement A slight loss of movement was found in all the methods

Roentgenological The X ray films were evaluated with regard to joint space cysts and sclerosis No trend at improvement or deterioration of any significance was found between the methods



Figure 5 Pain in motion versus observation time

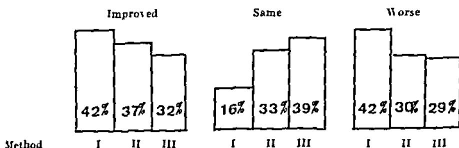


Figure 6 Walking capacity

DISCUSSION

The results of the present follow up examination must be evaluated with the background that pain and especially pain at rest have been the main indication for osteotomy

The overall results expressed as total assessment are in agreement with the earlier opinions (McMurray 1939 Shepard 1960 Robins & Piggot 1960 Harris & Kirwan 1964 Hirsch & Goldi 1968 Salenius et al 1971) that improvement is to be expected in about three quarters of the patients after an osteotomy

However the osteotomy regardless of whether it is performed with or without displacement has clear limitations From the present material we can only find a lasting positive effect on pain at rest The ability to relieve pain at rest in good (62–66 per cent) while the effect

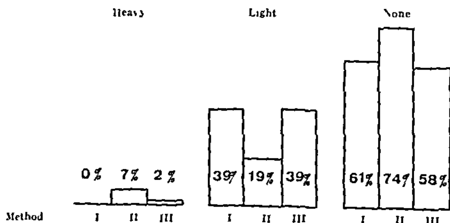


Figure Occupation

on pain on movement is poor (22–30 per cent). When comparing these findings with the results expressed as "total assessment" it is evident that relief of pain at rest was the main factor behind the patients own opinions of the result. If pain at rest is relieved the patient finds a definite general improvement in spite of possible persisting pain on movement. The explanation given by the patients is that pain on movement can be controlled by walking more slowly and carefully. If such activities do not lead to aching pain at rest in the evening and at night the patients are able to keep up or even increase their activities.

The difference in effect on pain at rest and on pain on movement also stresses the importance of the fact that pain at rest should be the main indication for osteotomy. Furthermore these two qualities of pain must properly be taken into account when assessing the results after treatment of osteoarthritis (Appel & Friberg 1972).

The lack of significant differences between displacement and non-displacement osteotomies, must cast serious doubts on the validity of the biomechanical theories of osteotomy effect. Our results are more compatible with the theory which claims that the effect of the osteotomy could be explained by improved vascular drainage from collum and caput femoris (Helal 1965, Philips 1966, Arnoldi et al. 1971, 1972).

The trent towards deterioration of the overall results with time indicates the possibility of further surgery. This possibility and the findings that no difference can be found regarding results between the methods show that osteotomies with medial displacement should be avoided since they will be a disadvantage if a total hip arthroplasty has to be performed later.

It has been claimed that roentgenological improvement of the osteoarthritic process can be expected after an osteotomy (Robins & Piggot 1960, Nissen 1960, Heimgartner 1969), but we, like Hirsch & Goldie (1968), could not observe any general trend of changes in the severity of the osteoarthritic process after the osteotomy.

As a total evaluation of the osteotomy in osteoarthritis of the hip we feel that in those patients where the indications for total hip arthroplasty or arthrodesis are controversial, osteotomy performed as treatment for pain at rest must still be considered as a valuable therapeutic procedure.

SUMMARY

The results after three different operative techniques for high femoral osteotomies performed as treatment for idiopathic osteoarthritis of the

hip are presented. A total of 112 operated hips with a mean observation period of 7.2 years were evaluated by clinical and roentgenological follow up examination.

No statistically significant differences regarding the results were found between displacement and non displacement osteotomies. The importance of the two different forms of pain from an osteoarthritic joint, namely pain at rest and pain on movement, is stressed. Regardless of the operative method used the effect on pain at rest was good while the effect on pain on movement was less pronounced.

The possible significance of these findings for the pathomechanism behind the effect of an osteotomy is discussed. The results indicate that high femoral osteotomy whether performed with displacement or not is a valuable therapeutic procedure in the treatment of pain at rest caused by osteoarthritis of the hip joint.

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RADIOLOGICAL CLASSIFICATION OF CONGENITAL PSEUDARTHROSIS OF THE TIBIA

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Accepted 7.iii.73

The results of operative treatment of congenital pseudarthrosis of the tibia are difficult to assess. In many cases they seem confusing and actually conflicting. This is due not only to the small number of cases included in most materials, but also to a heterogeneous definition of the materials and a large number of different therapeutic methods. Moreover, the follow-up period has often been insufficient. Lastly, the general assumption that all cases of congenital tibial pseudarthrosis are alike is presumably not correct (Nicoll 1969).

In order to decide whether different types of congenital tibial pseudarthrosis can be distinguished (Andersen 1972), and in order to be better able to assess the results of their operative treatment, I have investigated the possibility of classifying cases of congenital pseudarthrosis of the tibia into radiologically uniform types.

MATERIAL

Congenital pseudarthrosis of the tibia is taken to mean all congenital fractures of the tibia as well as pseudarthroses of the tibia arising after pathological fracture in a tibia with congenital anterior angulation. Cases in which systemic skeletal diseases have contributed to the occurrence of the fracture or pseudarthrosis were excluded. To obtain an accurate definition of the disease concept, cases arising after osteotomy on a lower leg with congenital anterior angulation were not included.

From orthopaedic departments and hospitals in Denmark, Norway, Sweden and USA I have collected 60 cases diagnosed as congenital pseudarthrosis of the tibia. For all cases I had access to complete records and X-ray films from the time treatment had been started until it had been completed or until 1970. In 5 cases the fracture was truly congenital. In 8 cases the pseudarthrosis had arisen after osteotomy and in the remaining 47 cases after fracture of the tibia. In the 5 congenital cases there were X-ray films of the affected leg from not later than one week after birth, and in 20 cases in which the pseudarthrosis arose after a fracture X-ray films from before the fracture were available. These 25 cases make up the present material.



Figure 1 d

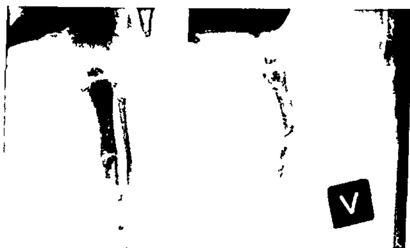


Figure 2 Case of the "clubfoot" type of congenital pseudarthrosis of the tibia



Figure 3 Case of the cystic type of congenital pseudarthrosis of the tibia.

out in 9 cases In one case of the sclerotic type the indication was infection in others pseudarthrosis in some of them associated with shortening

Seven patients aged 12 months to 18 years sustained 9 refractures With exception in which the refracture was due to a fall from a ladder the r[illegible] occurred within 12 months of clinical and radiological union Am ng the [illegible] cases there were 5 cases of refracture in 3 patients

DISCUSSION

Typing of congenital tibial pseudarthrosis has previou[illegible] tempted on the basis of the time of its onset (Fevre 1[illegible] (Camurati 1930) and its radiological appearances (A[illegible] well known that congenital pseudarthrosis of the tibia [illegible] by cystic and hourglass constriction of the bone (Bu[illegible] 1950 Lloyd Roberts & Shaw 1969) and a few cases ha[illegible] by fatigue-like fractures of the tibia (Sage 1971) [illegible] often seems to have been done for didactic or [illegible] Thus little is known about the relative number of [illegible] (Guillemmet & Ricard 19[illegible]8) and nothing about th[illegible] characteristics of the individual types although [illegible]

The frequency of refractures depends upon the operative intensity and upon the method used Thus Timmermanns (1965) publishing 23 cases from Van Nes clinic reported only 3 cases of refracture whereas Apoil (1970) found 4 cases of refracture among 13 treated cases

In the present material there were 7 patients with 9 refractures However the majority occurred among the pseudarthroses of the sclerotic type and took place as a rule less than one year after union had been ascertained It seems reasonable therefore to modify the demand of a long follow-up period and to let it apply mainly to pseudarthroses of the sclerotic type

A diagnosis of congenital pseudarthrosis of the tibia can be made with certainty only in case of a pathological fracture or pseudarthrosis in a lower leg with congenital anterior angulation The pseudarthrosis is rarely at birth and during the first months of life it may therefore be difficult to decide whether a case is one of congenital tibial pseud arthrosis in the pre pseudarthrosis stage However this decision is important especially in assessing the value of prophylactic procedudes On the background of the present study it must be justified to demand that the primary X ray films be published when assessing the results of prophylactic operations

SUMMARY

On the basis of 25 cases of congenital pseudarthrosis of the tibia examined radiologically before or immediately after the onset of the pseudarthrosis it is demonstrated that 4 radiologically different types may be distinguished In addition there is a clinical and prognostic difference between the four types This is of particular importance in assessing the results of prophylactic measures

ACKNOWLEDGEMENTS

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For the permission to use case reports and X ray films thanks are due to Dr B Eriksen Holstebro Denmark Professor T Hierton Uppsala Sweden Professor C. Hirsch Stockholm Sweden Dr E Hjalmar Larsen Copenhagen Denmark Dr E Millar Chicago Ill USA Dr J Mortens Copenhagen Denmark Dr V Mouritsen Kolding Denmark Dr J Saugmann Jensen Copenhagen Denmark Dr H Steel Philadelphia Pa USA Dr F Stelling Greenville Sc USA Dr T Wyller Oslo Norway

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Figure ? (a) 21 year old female injured in a traffic accident Severely co acetabular fracture
(b) Open reduction 5 days after injury
(c) Postoperative urse uneventful Normal follow up 9 years later u minimal he sis



Figure 3 (a) 50 year old male fell 2 m Vertical fracture of anterior column with dislocation of the femoral head



Figure 3 (b) The dislocation of the femoral head was easily reduced with skeletal traction through the tibial tuberosity and femoral trochanter Note that the acetabular fragments remain dislocated

Table 6 Posterior column fracture

	Results					
	Good	Fair	Poor	Unknown	Dead	Total
Without dislocation	8	–	–	–	1	9
With dislocation						
Operated	2	–	–	–	–	2
Not operated	5	3	–	–	2	10
Totals	15	3	–	–	3	21

Table 7 Anterior column fracture

	Results					
	Good	Fair	Poor	Unknown	Dead	Total
Without dislocation	10	–	–	2	1	13
With dislocation						
Operated	1	1	–	–	–	2
Not operated	7	1	2	4	3	17
Totals	18	2	2	6	4	32

Table 8 Transverse fracture

	Results					
	Good	Fair	Poor	Unknown	Dead	Total
Without dislocation	3	–	–	–	–	3
With dislocation						
Operated	–	–	–	1	–	1
Not operated	1	1	–	2	1	5
Totals	4	1	–	3	1	9

them the fracture was a minor one the fourth had an overlooked posterior rim fracture

Fracture of the posterior column (21 patients Table 6) Two patients with severe dislocation were operated upon with a good end result The 10 patients not operated on had moderate dislocation and had satisfactory results

Fracture of the anterior column (32 patients Table 7) Two patients with marked

Table 9 Other fracture

	Good	Fair	Poor	Unknown	Dead	Total
With dislocation						
Operated	1	–	2	2	2	7
Not operated	1	1	2	2	2	8
Totals	2	1	4	4	4	15

dislocation of the acetabular fracture had a satisfactory end result after operation Those patients not operated on usually had minor dislocations two with marked dislocations however had poor results (severe arthrosis clinically and roentgenologically)

Transverse fractures (9 patients Table 8) The number of the follow up patients is too small for evaluation

Others (15 patients Table 9) This group consisted of patients with a combined fracture of the anterior and posterior column—except for one patient with a fracture through the upper lateral part of the acetabulum They are usually highly displaced fractures and seven of them were operated on The patients with poor result not operated on had highly displaced fractures the others had minor dislocated fractures

DISCUSSION

The present series of acetabular fractures discloses a broad spectrum of injuries and their classification especially in retrospect is difficult With this reservation a classification was *found possible* and the results evaluated

Acetabular fractures without dislocation will have a good end result with bed rest only as was also found in the present series

On the other hand this treatment for dislocated fractures will leave a high percentage of the patients with poor results although some authors claim good results in smaller series (Austin 1971) The poor late results are due to the *rapid development of arthrosis* as shown in several reports (Urist 1948 Westerborn 1951 Stewart & Milford 1954 Pearson & Hargadon 1962 [illegible] & Hindmarsh 1970) The arthrosis is most often due to *incongruity of the acetabular fragments* especially when the *weightbearing parts of the acetabulum* are affected i e the upper and posterior parts and the more so the more dislocated the fracture Traction will *reduce a displaced femoral head* e g in central

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RECURRENT ANTERIOR DISLOCATION OF THE SHOULDER

The Eden Hybbinette Operation

LARS B SKOGLAND & PETER SUNDT

Accepted 11 iv 73

A number of operative procedures have been tried in the treatment of recurrent anterior dislocation of the shoulder In Scandinavia the Eden Hybbinette method is the one most often used with or without modifications The technique was described by the German Eden in 1913 and the Swede Hybbinette in 1932 (Palmer & Widen 1948)

Since 1946 only this method has been employed in the treatment of recurrent anterior dislocation of the shoulder at Sentralsykehuset in Trondheim In 1961 Lavik published a paper describing 22 cases treated up to 1955 The material presented here concerns patients treated during the following 13 year period The aim of this investigation has been to find out if the results (with regard to function and incidence of recurrence) are sufficiently good when compared with the results of other operations described

MATERIAL AND METHODS

During the period 1956–1968 a total of 45 patients were treated for recurrent anterior dislocation of the shoulder Two were affected bilaterally the survey thus covering 47 operated shoulders

In the 47 cases there were 13 female and 34 male shoulders In 22 cases the right shoulder was affected the left was affected in 25 cases The age at which primary dislocation occurred was under 30 years in 30 cases and under 20 years in 16 cases In as many as 7 cases the age at which the first dislocation occurred was 15 years or below The youngest was 7 years of age The average age at primary dislocation was 27 years

The primary dislocation occurred in 5 cases without significant injury e g swimming handstanding or hanging by the arms In many of the other cases it was impossible to determine whether the trauma was significant or not Thirty patients stated that their primary dislocation was caused by a direct blow to the shoulder Eight gave a history of a fall on the outstretched arm In four cases the type of injury was unknown

Table 3 Age distribution sex ratio and follow-up period

Age at operation	Sex F	Sex M	Follow up period (years) 12–14	10–12	8–10	6–8	4–6	2–4	Not able to be traced at follow up	Total
15 years	0	1				1				1
15–20 years	1	2			1		1		1	3
20–30 years	3	12	1		4	2	5	3		15
30–40 years	6	3	3	2		1	2	1		9
40–50 years	0	9		1	4		3	1		9
50–70 years	3	7	1	1	1	3	1	2	1	10
	13	34	5	4	10	7	12	7	2	47

Table 4 Symptoms and findings at follow-up examination

Follow up period (years)	No of patients	Pain	Limited movement	Arthrosis	Forced change of occupation	No of redisloc	Condition of transplant: In situ	Dislodged	Absorbed	No X ray
2	7	1	2	2	0	1	3	1	0	3
3–5	12	1	0	3	0	3	6	2	2	2
6–10	17	2	2	6	1	2	12	1	1	3
11–14	9	0	1	4	0	0	6	1	0	2
	45	4	5	15	1	6	27	5	3	10

complained of pain in the shoulder region belongs to the longest follow up group in which the incidence of osteoarthritis is highest Only one af these had daily pain He is a dock worker and had arthritic pains in his shoulder before operation The other three patients had symptoms only in connection with their work No patient complained of diminished power and during the follow up examination this was confirmed Motility of the shoulder was normal with the exception of 5 cases in which the external rotation was limited up to 20 All the examined patients could place their hand at the back of the neck and behind the back

Only one patient had changed his job because of his shoulder complaint He was a farmer and complained of pain in connection with heavy lifting In the follow up investigations deformity due to arthrosis

was found in 15 of the 35 X rayed patients but 6 of these had shown signs of arthritic changes preoperatively

In most cases the changes were extremely slight and only 3 or 4 of these had any symptoms In 24 of the 35 X rayed shoulders the trans plant was correctly positioned this represents 44 per cent

Table 5 Frequency and time of recurrence

	Operated	1st redis location	No of redis locations	Reoperated	Redis location
B O b 1955	1963	1968	1		
J B b 1907	1965	1965	numerous	1967	?
J K b 1940	1966	1966	numerous	1969	0
A G b 1902	1964	1964	6		
E.A b 1944	1967	1968	1		
M H b 1904	1961	1962	numerous	1965	0

Table 5 gives a more detailed account of the 6 cases in which redis location occurred The youngest patient in the survey is represented here He was 8 years of age at operation Redislocation occurred 5 years after operation during a gym class at school and his teacher reduced it He has had only the one recurrence and is otherwise satisfied with the result of the operation Redislocation for the other 5 patients oc



Figure 2 X ray showing the transplant a few weeks after operation

Table 3 Age distribution sex ratio and follow-up period

Age at operation	Sex F	Sex M	Follow up period (years) 12–14	10–12	8–10	6–8	4–6	2–4	Not able to be traced at follow up	Total
15 years	0	1				1				1
15–20 years	1	2			1		1		1	3
20–30 years	3	12	1		4	2	5	3		15
30–40 years	6	3	3	2		1	2	1		9
40–50 years	0	9		1	4		3	1		9
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Figure 2 X ray showing the transplant a few weeks after operation



Figure 3. Same patient 2 years postoperatively.

curred within the first year after operation, the shortest interval being two months. Definite injury appears to have been involved in at least three of these redislocations. X-rays showed the transplant correctly positioned in three of the redislocations. In one case the transplant was already dislodged 14 days after operation, in one case the transplant was absorbed and in another partly absorbed. Only 2 of our 6 patients with redislocation complained of pain in the shoulder.

DISCUSSION

Palmer & Widén (1948) alleged that the object of the Eden-Hybbinette method is to build out the anterior glenoid margin, enabling it to take up or fill out the posterolateral impression on the head of the humerus and thus hinder so called intracapsular subluxation.

Åke Jakobsson (1949) maintains that the transplant ought not to protrude further laterally than the intact part of the anterior glenoid margin, the intention being to build out the glenoid margin anteriorly. He therefore no longer employs the smaller limb in the L-formation transplant. He alleges that in doing this one also reduces the danger of postoperative arthrosis.

During their experimental studies Höhle et al. (1969) claim to have shown that the posterolateral impression on the head of the humerus ("coup d'en hachette") does not come in contact with the anterior glenoid margin even during forced movements. The basis for the Eden-Hybbinette method would in this case be false.

There has been considerable discussion as to the significance that

injuries to the capsule and labrum can have as aetiological factors in recurrent dislocation of the shoulder

De Palma (1950) discusses a neuromuscular imbalance in connection with recurrent shoulder dislocation He mentions amongst other things the hyperextension of the short rotators particularly subscapularis in primary dislocation These muscles do not regain their normal length and tone due to absence of or incorrect treatment (Hindmarsh & Lindberg 1967)

In our survey more than half of the cases (56 per cent) were immobilized for a week or less after primary dislocation Only two shoulders were immobilized for more than three weeks Much of the evidence suggests that some of the recurrent dislocations could have been avoided by longer immobilization after primary dislocation De Palma suggests immobilization for 8 weeks In our opinion three weeks would be reasonable

Many shoulder dislocations will however certainly become recurrent regardless of the length of immobilization time We found as did Lavik that many patients could reduce their own primary dislocation themselves or with the help of passers by but had to consult a physician when further dislocation occurred This might indicate that in the first instance merely subluxation occurred which later became complete dislocation

The average age of the first dislocation was in our material 27 years McLaughlin & MacLellan (1967) in a comparative study found that almost all recurrent dislocations began before the age of 30, and almost all non recurrent lesions occurred after the age of 30 years They concluded that "age seemed to be the essential factor in determining whether or not a primary dislocation was to be followed by recurrent episodes

In the study of this material we have not fully ascertained the reason for the Eden Hybbinette method giving such good results There is however much to indicate that capsule shrinkage "scar formation can be one of the important factors In 3 of 6 patients with postoperative redislocation X ray checks showed the transplant *in situ* On the other hand amongst some of the patients with excellent results the transplant was absorbed or displaced

It seems to us that the condition of the transplant is of little consequence as a deciding factor in the recurrence of dislocation as long as the transplant is not primarily dislodged

Review of the literature indicates certain deficiencies in all opera-

tions for recurrent dislocation of the shoulder Function has not always been optimal following the Putti Platts operation (Adams 1948 Osmond Clarke 1948) The Bankart operation is difficult and the good results obtained by Bankart (1938) have not always been duplicated in the hands of other surgeons (Day et al 1966)

In our series of Eden Hybbinette operations functional results have been good and recurrent dislocation limited to 6 8 per cent if redislocation after violent re-injury is excluded Few of our patients had any notable restriction of movement and all had good muscle power

The Eden Hybbinette method is a relatively simple operation and in our opinion represents a satisfactory treatment of a troublesome complaint

SUMMARY

During a 13 year period 45 patients with recurrent anterior dislocation of the shoulder have been operated 2 patients bilaterally employing the Eden Hybbinette method A total of 44 of these 47 shoulders have been followed up 6½ years being the average follow up time

At operation pathological changes in the anterior part of the humeroscapular joint were found in 41 cases

Moderate limitation of external rotation was found in 5 cases none had reduced muscle power The transplant was *in situ* in 27 of the 35 X ray examined shoulders Fifteen had arthritic changes but 6 of these had arthrosis preoperatively Six patients suffered redislocation but in 3 cases this occurred in connection with significant trauma

There is much to indicate that scar formation is a significant factor in this operative technique In half of the number of patients with *redislocation the transplant was in fact correctly placed* while it was absorbed or dislodged in several cases with good results Investigations also appear to show that incomplete immobilization after primary dislocation can be an additional aetiological factor in recurrent *dislocation* of the shoulder

The Eden Hybbinette operation seems to be a good alternative in the treatment of recurrent anterior dislocation of the shoulder

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Acta orthop scand 44 748–750 1973



CARL HIRSCH
1913 – 1973

IN MEMORIAM

Carl Hirsch Professor of Orthopaedic Surgery and Chairman at the Department of Orthopaedics Karolinska Institute Stockholm died suddenly on June 21st 1973 He was approaching his sixties born in Stockholm on July 10th 1913 It is with great sadness that all his Swedish and foreign colleagues have received the news of his tragic death

He graduated from the Karolinska Institute in 1938 where he received his surgical and orthopaedic training In 1944 he presented his Ph D thesis on chondromalacia of the patella This was one of the first biomechanical studies incorporating the physical histological and chemical properties of diseased cartilage

After having worked in the Department of Orthopaedics at the Karolinska Hospital he became leader and professor of the same department

at Uppsala in 1957 In 1961 he moved as professor to Gothenburg where he stayed until 1969 Following this he returned to Stockholm as professor at the Karolinska Institute

With the death of Carl Hirsch international orthopaedic surgery as well as biomechanics has lost one of its best minds His inspiring enthusiasm has guided and helped numerous research workers not only in Sweden but around the world He was granted honorary degrees in technology from London and Glasgow in 1968 and 1971 respectively As an honorary member of several international research organizations and orthopaedic societies he made numerous trips to different countries where he was in constant demand as a speaker in biomechanics

Carl Hirsch always had the ability to create a charming intellectual atmosphere both in a clinical and research environment This unique quality stimulated his co-workers and inspired them

His interest in biomechanical research started in the early forties at which time he was one of the very few in the world to foresee the impact that biomechanics would later have on orthopaedics some thing that is so plainly obvious today His first small biomechanical laboratory was housed in the Research Institute of King Gustaf V at Karolinska Institute and was later expanded both in Uppsala and in Gothenburg During the years he supervised more than forty Ph D theses and co authored hundreds of articles in the field of biomechanics which were published from his department many of these being written by foreign visitors His work on the lumbar and cervical discs is particularly well known and while his investigations on the physical properties of bone and cartilage today in the age of research into the mechanics of bone replacement arthroplasty and connective tissue seem elementary this was not so obvious thirty years ago when Carl Hirsch entered the field

Thus in biomechanics Carl Hirsch was a pioneer and he became a world leader in a rapidly expanding field In most university centres today engaged in orthopaedic research one can find a biomechanics laboratory and many of them are headed by his former pupils No less than ten of these have become professors and chairmen of various orthopaedic institutions in Scandinavia in the United States and other countries

We who have been fortunate enough to collaborate with Carl Hirsch for some time always wondered where he found his sparkling energy He was able not only to carry out pure original research but also to advance clinical orthopaedics His scientific mind was always applied

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There are many around the world who mourn Carl Hirsch's death. The loss is great first of all for his family, wife and children, but also for all of us who became a friend of a man who was so richly endowed with inner strength, warmth and intellectual energy. The memory of Carl Hirsch will always be honoured and his scientific glow kept alive

Alf Nachemson

Acta orthop. scand. 44, 101–106, 1973

PROCEEDINGS OF THE SWEDISH ORTHOPEDIC ASSOCIATION

KARLSTAD, SWEDEN, MAY 4–5, 1973

Editor Bo E. Nilsson

THE EFFECT OF FENESTRATION ON INTRAOSSEOUS PRESSURE AND PAIN AT REST IN PATIENTS WITH HIP OSTEOARTHRITIS—A PRELIMINARY REPORT

J. Åström (Orthop. Dept., Umeå)

Increased intraosseous pressure has been demonstrated in the proximal end of the femur in cases of osteoarthritis of the hip and a relationship between the increased pressure and pain has been suggested. An 8 × 15 mm hole was made in the cortex of the trochanteric region in 19 patients with hip osteoarthritis and pain at rest. A pedicle muscle graft was implanted in the hole. A small but significant immediate decrease of the intraosseous pressure in the head and the neck of the femur was recorded in 9 out of 9 patients. In 6 patients investigated 3 months after the operation the pressure was lower than immediately after the operation. Eleven out of 14 were relieved of pain or had less pain 3 months after operation but after 12 months the results were satisfactory in only 4 out of 8. The procedure is a possible alternative in selected cases of osteoarthritis with pain at rest as the main symptom.

INTRAOSSEOUS PRESSURE FOLLOWING TIBIA SHAFT FRACTURE

P. H. Widmark (Orthop. Dept., Malmö)

The intraosseous pressure was measured in 19 patients with healing tibial shaft fractures. The pressure was reduced proximally as well as distally to the fracture. The pulse pressure amplitude was not changed.

RESULTS OF THE PUTTI PLATT PROCEDURE FOR SHOULDER DISLOCATION

G. Lundholm (Orthop. Dept., Karlstad)

Eighty seven cases of recurrent shoulder dislocation were reinvestigated ... years (average 8 years) after treatment with the Putti Platt procedure. ... per-operative complications were recorded. In no case had dislocation ... the operation. Thirty-one patients complained of usually minor pain and one had been forced to change his occupation. In ... examination of the operated joint was performed and in ... of rotational motion was decreased by 20° or more.

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Alf Nachemson

INTRAMEDULLARY PRESSURE CHANGES DURING THE CEMENTING OF FEMORAL HEAD PROSTHESIS

S Olerud (Orthop Dept., Uppsala)

It was demonstrated that the pressure in the marrow cavity of the femur increases significantly and remains increased for a few minutes when a hip prosthesis is inserted and cemented. It was suggested that the content of the marrow cavity when under pressure, may cause circulatory changes in the cortical bone of the femur and result in a loosening of the pro thesis Against the background of sudden death described in hip arthroplasties the possible systemic effects of the cement hardener and the increased pressure in the marrow cavity were discussed

EARLY RESULTS FOLLOWING LOW FRICTION ARTHROPLASTY OF THE HIP ACCORDING TO CHARNLEY

H Semb (Orthop Dept., Karlstad)

The material consisted of 66 hips in 21 men and 44 women The follow up varied from 6 to 18 months and was aimed mainly at assessment of complications There was one death, 5 infections 7 haematomas 2 cases of thrombophlebitis no pulmonary emboli 12 wirebreaks and 3 dislocations The preliminary results were satisfactory

EXPERIMENTAL FRACTURES OF THE TALUS

L Peterson & E Dahlberg (Orthop Dept II Goteborg)

A study has been carried out the object of which has been to produce experimental fractures of the talus It is intended that these experiments should serve as a basis for future studies on the influence of fractures on the vascular supply of the talus A cadaver foot in an ordinary shoe was fitted in a device with adjustable wires attached to the heel and the forefoot Force was applied by a swinging pendulum which truck the mid sole of the foot Theoretical calculations suggested that fractures occur by bending forces with the tibia against the talus and *also* by *shearing* forces when the heel is well fixed. The practical experiments verified completely the theoretical calculations

THE DASHBOARD FRACTURE—LONG TERM RESULTS OF SURGICAL TREATMENT

A Waller (Surg Dept., Karlstad)

Three types of dashboard fractures of the acetabulum were described Type 1 with a small posterior fragment which should not be operated on type 2 with a large single fragment which should be treated by open reduction and osteosynthesis and type 3 the comminuted fractures which usually hould be operated upon Out of the two latter types one th rd result in osteoarthritis of the hip and one fifth in necrosis of the head of the femur Out of 63 operated cases 45 were classed as excellent or good at long term follow up most of the poor results belonged to type 3 Myositis ossificans a common complication could not be demonstrated to cause poor results The surgical procedure included three weeks of traction postoperatively

POSTOPERATIVE WOUND INFECTION IN OUTPATIENTS AND PATIENTS ADMITTED TO HOSPITAL

B Georén (Orthop Dept Umeå)

The rate of postoperative infection was studied in 510 patients wh) had undergone foot operations mostly for bunions and hammer toes The rate was significantly greater more than doubled in patients admitted to hospital before the operation as compared to those who were outpatients Interaction of variables such as age and sex of the patients choice of surgeon or operating room could not explain the difference

LATE COMPLICATION AFTER BUNION SURGERY

J Hansson (Lundby Medical Center Goteborg)

Among 190 cases operated on because of bunion by subcapital osteotomy or by the Keller procedure 7 developed stress fractures in the 2nd 3rd or 4th metatarsals The age of these patients varied from 16 to 60 and the time interval between surgery and diagnosis of the fracture was 3–10 months In all 7 cases the fractures healed without further complications It is suggested that the changes in magnitude and direction of weightbearing on the bones of the foot after surgery is the ca ise of this complication

A 2 YEAR FOLLOW UP OF CHARNLEY HIP ARTHROPLASTIES

J Stenport (Orthop Dept Sodersjukhuset Stockholm)

Two hundred Charnley hip arthroplasties were reinvestigated 2 years after th operation Seventy five per cent of the operations were performed on patients in the age group 56–7o mainly with osteoarthritis The variables of pain range of motion and function were ranked before the operation and at the time of the re investigation It could be demonstrated that the operation resulted in efficacious relief of the pain increased range of motion and increased function The result ere classified as poor 7 per cent fair 5 per cent good 30 per cent and excellent 58 per cent In 10 hips the endoprosthesis had been removed

PROPHYLACTIC ANTIBIOTIC THERAPY IN HIP ARTHROPLASTIES

W Wantschura (Orthop Dept Norrkoping)

In J rthroplasties according to the Charnley Müller procedure antibiotic pr phylaxis was given including Penicillin in intravenous infusion from the day f the operati n to the fourth postoperative day and Cloxacillin to the end of the th r l post perative week There were two incidences of exantaema. Nausea and diar h ea w noted in 12 cases in all instances after Cloxacillin treatment No infe t n occurred Th rate f complications was otherwise normal The results of the op tive p cedure ver very good with regard t) pain range of motion and functi n l n pl lactic chem therapy is recommended in hip arthroplasties

INTRAMEDULLARY PRESSURE CHANGES DURING THE CEMENTING OF FE I ORAL HEAD PROSTHESIS

S Olerud (Orthop Dept Uppsala)

It was demonstrated that the pressure in the marrow cavity of the femur increases significantly and remains increased for a few minutes when a hip prosthesis is inserted and cemented It was suggested that the content of the marrow cavity when under pressure may cause circulatory changes in the cortical bone of the femur and result in a loo ening of the prosthesis Against the background of sudden death described in hip arthroplasties the possible systemic effect of the cement hardener and the increased pressure in the marrow cavity were di cussed

EARLY RESULTS FOLLOWING LOW FRICTION ARTHROPLASTY OF THE HIP ACCORDING TO CHARNLEY

H Semb (Orthop Dept Karlstad)

The material consisted of 66 hips in 21 men and 44 women The follow up varied from 6 to 18 months and was aimed mainly at assessment of complications There was one death, 5 infections 7 haematomas 2 cases of thrombophlebitis no pulmonary emboli 12 wirebreaks and 3 dislocations The preliminary results were satisfactory

EXPERIMENTAL FRACTURES OF THE TALUS

I Peterson & E Dahlberg (Orthop Dept II Goteborg)

A study has been carried out the object of which has been to produce experimental fractures of the talus It is intended that these experiments should serve as a basis for future studies on the influence of fractures on the vascular supply of the talus A cadaver foot in an ordinary hoe was fitted in a device with adjustable wires attached to the heel and the forefoot Force was applied by a swing ing pendulum which struck the mid sole of the foot Theoretical calculations sug gested that fractures occur b bending forces with the tibia against the talus and *also* by *shearing* forces whe the heel is well fixed. The practical experiments verified completely the theoretical calculations

THE DASHBOARD FRACTURE—LO G TERM RESULTS OF SURGICAL TREATMENT

A Waller (Surg Dept Karlstad)

Three types of dashb ard fr ctures of the acetabulum were described Type 1 with a small posterior fr gment which should not be operated on type 2 with a large single fragment which should be treated by open reduction and osteosynthesis and type 3 the comminuted fra tures which usuall should be operated upon Out of the two latter type ne th ird re ult in osteoarthritis of the hip and one fifth in necrosis of the head of the f mur Out of 63 operated cases 45 were classed as excellent or good at long term f llow up most of the poor results belonged to type 3 Myositis ossificans a c mm n c mplication could not be demonstrated to cau e poor results The surgi al pr edure included three weeks of traction postoperatively

POSTOPERATIVE WOUND INFECTION IN OUTPATIENTS AND PATIENTS ADMITTED TO HOSPITAL

B Georén (Orthop Dept Umeå)

The rate of postoperative infection was studied in 510 patients who had undergone foot operations mostly for bunions and hammer toes The rate was significantly greater more than doubled in patients admitted to hospital before the operation as compared to those who were outpatients Interaction of variables such as age and sex of the patients choice of surgeon or operating room could not explain the difference

LATE COMPLICATION AFTER BUNION SURGERY

J Hansson (Lundby Medical Center Göteborg)

Among 190 cases operated on because of bunion by subcapital osteotomy or by the Keller procedure 7 developed stress fractures in the 2nd 3rd or 4th metatarsals The age of these patients varied from 16 to 60 and the time interval between surgery and diagnosis of the fracture was 3–10 months In all 7 cases the fractures healed without further complications It is suggested that the changes in magnitude and direction of weightbearing on the bones of the foot after surgery is the cause of this complication

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Three types of dashboard fractures of the acetabulum were described. Type 1 with a small posterior fragment which should not be operated on, type 2 with a large single fragment which should be treated by open reduction and osteosynthesis and type 3 the comminuted fractures which usually should be operated upon. Out of the two latter types one third result in osteoarthritis of the hip and one fifth in necrosis of the head of the femur. Out of 63 operated cases [illegible] were classed as excellent or good at long term follow up. Most of the poor r[illegible] [illegible] to type 1. Myositis ossificans, a common complication, could n[illegible]t [illegible] cause poor results. The surgical procedure included three weeks of [illegible]

and it was stressed that exploration of the joint and clearing the acetabulum of loose fragments is important. Finally the radiological procedure must always include the posterior projection of the acetabulum.

HEMIPELVECTOMY—CASE REPORTS

G. Kollberg (Orthop. Dept. Karlstad)

The hemipelvectomy procedure was described in 3 cases, 2 with angiosarcoma and one with epithelial cancer. It was concluded that bone tumour surgery of this magnitude would benefit from being concentrated at one or a few centres in Scandinavia.

HAEMANGIO-PERICYTOMA—A CLINICAL, ROENTGENOLOGICAL AND PATHOLOGICAL ANATOMICAL STUDY WITH CASE REPORTS

J. Moller Nielsen, L. Angervall & B. Stener (Orthop. Dept. II, Göteborg)

REGIONAL BLOCK ANAESTHESIA FOR SHOULDER OPERATIONS

L. Dahlstedt & A. Mortasawi (Södersjukhuset, Stockholm)

Supraclavicular block of the arm plexus combined with superficial blocks of the supraclavicular and intercostobrachial nerves was tested with shoulder operations. For the plexus block 0.5 per cent bupivacain-chloride was used and for the superficial 1 per cent mepivacain-chloride. In 21 shoulder operations, all including operating in the area around caput humeri, this type of anaesthesia was satisfactory and without complications.

TECHNETIUM SCINTIGRAPHY IN HIP ARTHROPLASTY

C. Hallin (Dept. of Orthop. Surg., Uppsala)

Scintigraphy using 99mTechnetium labelled polyphosphate showed distinctly increased uptake in hips with clinical and radiological signs of loosening of the prosthesis. The uptake was also increased in cases with uncertain radiological signs. The uptake reflects the metabolic activity in the bone which surrounds the prosthesis. The activity is probably increased for a considerable time before radiological signs of loosening become evident. Scintigraphy therefore may prove to be a useful prognostic-diagnostic method for predicting complications after hip arthroplasty.

STRONTIUM 85 SCINTIMETRY IN HIP ARTHROPLASTY

J. S[illegible] and [illegible] (Orthop. Dept. Lund)

D[illegible] scintimetry with Strontium 85 was carried out in patients operated on with total hip replacement according to Charnley. In all cases the uptake was initially increased but in cases without complications the values became stabilized at a low level within the first 8-10 months. In infected cases (increased ESR, draining [illegible] radiological signs) the uptake remained high. Also in cases with

pain in whom the diagnosis of postoperative infection had not been established the uptake was increased It is suggested that this method may be used to predict postoperative infection

HARDNESS OF THE SUBCHONDRAL BONE OF THE TIBIA CONDYLLS IN OSTEOARTHRITIS AND RHEUMATOID ARTHRITIS

P Ieteim I Goldie & E Dahlberg (Orthop Dept II Goteborg)

The hardness of bone defined as its capacity to resist the impact of a penetrating agent, is believed to be directly related to the degree of mineralization The hardness of the subchondral bone of the tibial condyles was tested by the Brinell method which involves a steel ball being pressed into the tested material under standardized conditions The hardness was decreased in patients with osteoarthritis and rheumatoid arthritis when compared to the normal The hardness increased with age in normal bone whereas in osteoarthritis and rheumatoid arthritis it remained unchanged There was no difference between the sexes and steroid treatment did not influence the hardness The results are in part contradictory to those of other investigators

ASYMMETRY OF THE EPIPHYSEAL NUCLEUS IN THE FEMORAL HEAD IN STABLE AND UNSTABLE HIP JOINTS

R. Lemperg (Orthop Dept) *B Liliequist* (Diagn Neuradiology) & *S A Mattsson* (Orthop Dept Umeå)

An investigation was carried out to study the incidence of asymmetry of the ossification centre in the femoral head in children aged 3 to 12 months

Asymmetry of the radiopaque osseous nucleus in the femoral head was present in about 25 per cent of all infants with clinically normal hips Equalization occurred with increasing size of the nuclei

In hip joints with the diagnosis unilateral preluxation at birth, there was a statistically significantly higher frequency of smaller nuclei on the clinically affected side Equalization proceeded with increasing age

The finding of a smaller osseous nucleus in one femoral head in infants below the age one year is without diagnostic value in the diagnosis of suspected hip instability

ORIENTAL ORTHOPAEDICS

M Zayer (Orthop Dept Lund)

The term "orthopaedics" was first used by Nicolas Andry in Paris in 1741 The first orthopaedic operation on record is however the creation of Eve out of the rib of Adam From *prehistoric times* fractures osteomyelitis arthritis bone tumours amputation and trepanations are documented One of the oldest cultures in the world *Mesopotamia* (4000–3000 B C.) had clergical physicians as well as surgeons who treated fractures rheumatism and neuralgia. From the *Egyptian* mummies and sculptures the presence of Pott s disease arthritis paralysis dwarfism poliomyelitis osteoarthritis spondylitis amputations and other deformities can be

deduced From *Chinese medical textbooks* one can learn about braces for the spine for injured knees and fractured forearms and about exercises suitable for the different months of the year Avicenna was the most famous physician of the Eastern Califate of Bagdad His Al canon was translated into Latin in 30 editions and it dealt with dislocations fractures of the nose and the clavicle treatment of dislocated vertebrae with manipulation as well as the art of curing l se which the author considered to be a disease The most famous of the surgeons in the Western Califate of Cordoba was Abulcasis who described the use of the branding iron and operations such as trepanations amputations and operations for aneurysma Cordoba at that time represented the light of the East in the medieval darkness of Western medicine

ORTHORADIOGRAPHIC MEASUREMENT OF ANGULAR DEVIATION OF THE KNEE JOINT

I Edholm O Lindahl B Lindholm R Myrnerl K F Olsson & F Wennberg
(Orthop Dept., Linköping)

On the supine patient the leg was fixed to the table and the foot was first drawn medially and then laterally At each provocation three films were exposed one each of the hip the knee and the ankle A coordinate pattern was included on the films and by the three films correctly located in a coordinate system an "orthoradiographic projection was obtained of the hip knee and ankle In a group of control cases the forces applied to the foot caused it to move on the average within an angle of 3 The line from hip to ankle on the average passed through the middle of the knee

TIBIAL OSTEOTOMY IN GONARTHROSIS

I Edholm O Lindahl B Lindholm R Myrnerl K F Olsson & F Wennberg
Orthop Dept Linkoping)

Twenty eight patients with high tibial osteotomy have been examined with orthoradiographical determination of the range of lateral deviation before and after operation No correlation was found between the degree of correction attained by the procedure and the patient s judgement of pain at rest functional pain and general well being However the time of observation was short (8 months) The orthoradiographical examination was found to be of great value for the evaluation of the patients before and after operation